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PhD Thesis

ENHANCING EMERGENCY
RESPONSE AND BLS TRAINING
FOR LAYPEOPLE AND
FIRST RESPONDERS THROUGH
SMART GLASSES:
FEASIBILITY AND IMPACT OF
VIDEO-ASSISTED INTERVENTIONS

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ENHANCING EMERGENCY RESPONSE AND BLS TRAINING FOR LAYPEOPLE AND FIRST RESPONDERS THROUGH SMART GLASSES: FEASIBILITY AND IMPACT OF VIDEO-ASSISTED INTERVENTIONS

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CONFLICT OF INTEREST

Silvia Aranda García has no conflict of interest to declare regarding this thesis.

Success is not the key to happiness.
Happiness is the key to success. If you love
what you are doing, you will be successful.

- *Albert Schweitzer* -

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1. LIST OF PUBLICATIONS

1 LIST OF PUBLICATIONS

Thesis by compendium of publications indexed in the Journal Citation Report and the Scopus index (article 41 of the Regulations for Doctoral Studies - USC). List of publications:

1. **Aranda-García S**, Santos-Folgar M, Fernández-Méndez F, Barcala-Furelos R, Pardo Ríos M, Hernández Sánchez E, Varela-Varela L, San Román-Mata S, Rodríguez-Núñez A. “**Dispatcher, Can You Help Me? A Woman Is Giving Birth**”. A Pilot Study of Remote Video Assistance with Smart Glasses. *Sensors (Basel)*. 2022 Dec 30;23(1). <https://doi.org/10.3390/s23010409>
2. Barcala-Furelos R, **Aranda-García S**, Otero-Agra M, Fernández-Méndez F, Alonso-Calvete A, Martínez-Isasi S, Greif R, Rodríguez-Núñez A. **Are smart glasses feasible for dispatch prehospital assistance during on-boat cardiac arrest? A pilot simulation study with fishermen**. *Intern Emerg Med*. 2023 Apr 4; <https://doi.org/10.1007/s11739-023-03251-6>
3. **Aranda-García S**, Barrio-Cortes J, Fernández-Méndez F, Otero-Agra M, Darné M, Herrera-Pedroviejo E, Barcala-Furelos R, Rodríguez-Núñez A. **Dispatcher-assisted BLS for lay bystanders: A pilot study comparing video streaming via smart glasses and telephone instructions**. *Am J Emerg Med*. 2023 Sep;71:163–8. <https://doi.org/10.1016/j.ajem.2023.06.035>
4. **Aranda-García S**, Otero-Agra M, Fernández-Méndez F, Herrera-Pedroviejo E, Darné M, Barcala-Furelos R, Rodríguez-Núñez A. **Augmented reality training in basic life support with the help of smart glasses. A pilot study**. *Resusc Plus*. 2023 Jun;14:100391. <https://doi.org/10.1016/j.resplu.2023.100391>
5. **Aranda-García S**, Otero-Agra M, Berlanga-Macías C, Rodríguez-Núñez A, Barcala-Furelos R, Domingo J, et al. **New communication tool for basic life support training: smart glasses. A quasi-experimental study**. *Med Intensiva*. 2023 Oct; <https://doi.org/10.1016/j.medine.2023.10.011>. © 2023 Elsevier España, S.L.U. y SEMICYUC. Todos los derechos reservados.
6. **Aranda-García S**, Martínez-Isasi S, Barcala-Furelos R, Darné M, Rodríguez-Núñez A. **Augmented reality smart glasses. A new resuscitation training tool or a worthless gadget?** *Intern Emerg Med*. 2023. [manuscript accepted October 31]

2.ABSTRACTS

2 ABSTRACTS

2.1 ABSTRACT

Note:

This abstract is a condensed version of the main. The references were cited in the English manuscript.

INTRODUCTION. The global incidence and outcomes of out-of-hospital cardiorespiratory arrest (OHCA) vary significantly worldwide. Bystander actions play a crucial role in influencing the survival and outcomes of OHCA victims because when CPR was initiated by bystanders before the arrival of emergency medical services (EMS) resulting in a survival rate twice as high as when initiated by EMS. Unfortunately, individuals who could assist in such emergencies may lack the necessary knowledge, attitudes, and basic life support (BLS) skills, leading to up to 65% of OHCA events going unattended until ambulance arrival. Bystander intervention is also vital in other out-of-hospital emergencies, such as unplanned childbirths, which can be challenging when they occur far from healthcare facilities or suddenly in multiparous women. The 35% of the unplanned out-of-hospital childbirths receiving no medical care and being attended by family members or witnesses.

Recognizing the critical role of bystander intervention in emergencies, the European Resuscitation Council (ERC) has developed strategies to enhance the response. This includes training EMS dispatchers to provide telephonic assistance and educating the public to improve readiness in emergency situations. These efforts aim to strengthen and optimize the response to critical events, with a focus on resuscitation-related strategies but also applicable to various out-of-hospital emergencies. ERC guidelines emphasize community responses and training EMS dispatchers in providing telephone assistance for BLS and high-quality CPR. However, telephone assistance has limitations due to its reliance on verbal communication, which doesn't always meet expected standards. Challenges faced by dispatchers include difficulties in assessing a victim's breathing and issues with activating hands-free speaker functions.

Recent technology advancements have introduced video calls on smartphones, showing potential benefits in improving response rates and BLS quality. Video-assisted communication with smart glasses has also been explored, offering real-time visual assessment and guidance. While promising, it may have drawbacks, such as potential delays and the need for a second person to hold and frame the smartphone during video calls.

ERC's second strategy involves educating the public in BLS to ensure effective responses to OHCA and other emergencies. Smart glasses, with their immersive augmented reality (AR) capabilities, could offer advantages in both real-time care and BLS training. These devices have potential in revolutionizing how bystanders respond to critical situations by providing real-time assistance and facilitating learning through AR.

OBJECTIVES. Considering all of the aforementioned, the general **objective** was to evaluate the feasibility of employing augmented reality with video-assisted intercommunication via smart glasses and analyze the enhancements it contributes to performance and training during simulated out-of-hospital emergencies attended by laypeople. The thesis is structured into three sections: a) Feasibility of devices, b) Video-assistance potential role in out-of-hospital emergencies, and c) BLS Training with the support of AR. Accordingly, each section has its respective specific objectives: a) to assess the feasibility of communication through videocalls using smart glasses in an out-of-hospital setting to determine its applicability in a simulated cardiac arrest scenario managed by laypersons, b) to assess the impact of utilizing smart glasses for video communication with the emergency dispatcher on the performance of bystanders in simulated out-of-hospital emergency situations, with a focus on protocol adherence and the enhancement of assistance techniques' quality in such emergencies, and c) to analyze augmented reality tele-training through smart glasses as an educational tool for cardiac arrest management.

MATERIAL AND METHODS. The **methodology** of the doctoral thesis comprised six research studies: three quasi-experimental randomized pilot studies, one descriptive and comparative study, one letter to the editor, and one single-group pre-posttest pre-experimental study. All studies adhered to the Declaration of Helsinki principles and were approved by the respective Ethics Committees. Informed consent was obtained from all participants. In all the studies, the participants received brief training (less than 5 minutes) to familiarize themselves with the smart glasses' basic functions, which were connected via a 4G wireless network and equipped with the Vuzix Remote Assist App.

Simulations were conducted in as realistic as possible settings, including scenarios such as a small boat, a college building, a beach, and a university classroom. Participants were engaged in out-of-hospital emergency simulations or training. For the simulation scenarios a resuscitation manikin was connected to various equipment, and data were collected a series of variables and parameters, including BLS protocol adherence, chest compression quality, performance times, self-perceptions of performance, and ease of use of the smart glasses.

For studies related to dispatcher assistance, participants communicated via video call with smart glasses while receiving guidance from an emergency expert. These groups were compared with scenarios with control conditions where there was no assistance or traditional phone assistance. In training studies, participants learned with video assistance via smart glasses in communication with a telematic trainer, and their performance in OHCA scenarios was assessed, recorded and compared with baseline or control groups following traditional face-to-face teaching. Statistical analyses were performed using IBM SPSS Statistics software, including descriptive statistics, t-tests, chi-square tests, effect size calculations, and significance testing at $p < 0.05$.

RESULTS. The **results of the Usability** section showed that assistance through smart glasses was needed in 72% of the BLS steps, which enabled all participants to perform the ABC approach and use AED correctly. Feasibility was proven that dispatcher's feedback through smart glasses helped to improve bystanders' performance, as after dispatcher gave feedback via smart glasses, only 3% of skills were incorrect. Comparison of on-scene instructor vs. smart glasses' assessment by dispatcher differ in 8% of the analysed skills: greatest difference in the "incorrect hand position during CPR" (on-scene: 33% vs. dispatcher: 0%). When comparing the

1st minute (with no-assistance) with 2nd minute (with video assistance), there were only significant differences in the percentage of compressions with correct depth (1st: $48 \pm 42\%$, 2nd: 70 ± 31 , $p = 0.02$). Otherwise, the **results of the Video-assistance** in out-of-hospital emergencies section showed that nine of the 14 smart glasses-video assistance (SG-VA) rescuers correctly completed the BLS protocol compared with none of the C rescuers assisted via smartphone-audio assistance ($p = 0.01$). A significantly higher number of SG-VA rescuers successfully opened the airway (13 vs. 5, $p = 0.002$), checked breathing (13 vs. 8, $p = 0.03$), correctly positioned the AED pads (14 vs. 6, $p = 0.001$), and warned bystanders to stay clear before delivering the shock (12 vs. 0, $p < 0.001$). No significant differences were observed for performance times or chest compression quality. The mean compression rate was 104 compressions per minute in the SG-VA group and 98 compressions per minute in the SP-AA group ($p = 0.46$); mean depth of compression was 4.5 cm and 4.4 cm ($p = 0.49$), respectively. Furthermore, the **results of the Video-assistance for the unplanned childbirth** showed that the midwife's video assistance with smart glasses allowed 35% of the participants to perform the complete protocol. No C participant (no assistance) was able to perform it ($p = 0.005$). All protocol variables were significantly better in the intervention group than in the C ($p < 0.05$). Telemedicine through video assistance with smart glasses was feasible so that a lifeguard with no knowledge of childbirth care can act according to the recommendations in a simulated, unplanned, uncomplicated out-of-hospital childbirth. Finally, **results regarding the AR for BLS training** showed that after the training all participants were able to deliver good quality BLS, with results comparable to those obtained when real time remotely guided by the instructor through the smart glasses. Mean chest compression rate was significantly higher when not guided (113 /min vs. 103 /min, $p = 0.001$). When not assisted, the participants spent less time delivering the sequential BLS steps than when assisted while training. Moreover, when comparing AR learning with smart glasses to traditional in-person teaching, in most of the BLS protocol variables, the resuscitation quality and performance times, there were no statistically significant differences between groups. There were significant differences (in favor of the smart glasses) in the assessment of breathing (smart glasses: 100 %, C: 81 %; $p = 0.013$), the not-to-touch warning before applying the shock (smart glasses: 79 %, C: 52 %; $p = 0.025$) and compressions with correct recoil (smart glasses: 85 %, CG: 32 %; $p = 0.008$).

CONCLUSIONS. The **conclusions** of this doctoral thesis can be categorized into three sections, each one corresponding to a specific hypothesis and linked objective addressed in the various articles within this compilation of publications. The conclusions based on each hypothesis are: H1 - C1: Smart glasses are feasible for out-of-hospital emergencies, even in challenging environments, with good Wi-Fi connectivity. H2a - C2a: Video streaming via smart glasses improves information transfer in emergencies, enhancing BLS and AED use without compromising chest compression quality. H2b - C2b: Smart glasses enable telemedicine for childbirth scenarios, benefiting both technical and non-technical skills. H3 - C3: Augmented reality tele-training with smart glasses is valuable for BLS education for laypersons and can may be as effective as traditional methods. In summary, smart glasses show promise for improving emergency response, childbirth assistance, and BLS training.

2.2 RESUMEN

Nota:

Este resumen es una versión reducida del documento principal redactado en castellano. Las referencias bibliográficas fueron citadas en el manuscrito en inglés.

INTRODUCTION. La incidencia global y el pronóstico del paro cardiorrespiratorio extrahospitalario (PCEH) varían significativamente en todo el mundo. Las acciones de los testigos desempeñan un papel crucial a la hora de influir en la supervivencia y los resultados de las víctimas de PCEH porque cuando los inician la reanimación cardiopulmonar (RCP) antes de la llegada de los servicios de emergencias médicas (SEM), la tasa de supervivencia es dos veces mayor que cuando la iniciaron los SEM. Desafortunadamente, las personas que podrían ayudar en tales emergencias pueden carecer de los conocimientos, las actitudes y las habilidades de soporte vital básico (SVB) necesarios, lo que lleva a que hasta el 65% de los PCEH queden desatendidos hasta la llegada de la ambulancia. La intervención de los espectadores también es vital en otras emergencias extrahospitalarias, como los partos no planificados, que pueden ser un desafío cuando ocurren lejos de los centros de atención médica o repentinamente en mujeres multíparas.

El 35% de los partos extrahospitalarios no planificados no reciben atención médica y son atendidos por familiares o testigos.

Reconociendo el papel fundamental de la intervención de testigos en emergencias, el Consejo Europeo de Reanimación (ERC, por sus siglas en inglés) ha desarrollado estrategias para mejorar la respuesta. Esto incluye capacitar a los teleoperadores de SEM para brindar asistencia telefónica y educar a la población para mejorar la preparación en situaciones de emergencia. Estos esfuerzos tienen como objetivo fortalecer y optimizar la respuesta a eventos críticos, con un enfoque en estrategias relacionadas con la reanimación, pero también aplicables a otras emergencias extrahospitalarias. Las pautas del ERC enfatizan las respuestas comunitarias y la capacitación de los teleoperadores de SEM para brindar asistencia telefónica para SVB y RCP de alta calidad. Sin embargo, la asistencia telefónica tiene limitaciones debido a que depende de la comunicación verbal, que no siempre cumple con los estándares esperados. Los desafíos que enfrentan los teleoperadores incluyen dificultades para evaluar la respiración de la víctima y problemas para activar la función de activar los altavoces de las manos libres del smartphone. Los avances tecnológicos recientes han introducido videollamadas en smartphones, lo que muestra beneficios potenciales para mejorar las tasas de respuesta y la calidad de SVB. También se ha explorado la comunicación asistida por vídeo con smart glasses, que ofrece una asistencia en base a la visión del escenario por la cámara frontal del wearable. Si bien es prometedor, puede tener inconvenientes, como posibles retrasos en los tiempos de actuación y la necesidad de que una segunda persona sostenga y encuadre el teléfono inteligente durante las videollamadas.

La segunda estrategia de ERC implica educar a la población en SVB para garantizar respuestas efectivas a PCEH y otras emergencias. Las smart glasses, con sus capacidades inmersivas de realidad aumentada, podrían ofrecer ventajas tanto en la atención en tiempo real como en el entrenamiento en SVB. Estos dispositivos tienen potencial para revolucionar la forma en que

los espectadores responden a situaciones críticas al brindar asistencia en tiempo real y facilitar el aprendizaje a través de realidad aumentada.

OBJETIVO. Teniendo en cuenta todo lo mencionado anteriormente, el objetivo general de esta tesis fue evaluar la viabilidad de emplear la realidad aumentada con intercomunicación asistida por video a través de smart glasses y analizar las mejoras que aporta en el desempeño y la formación durante situaciones simuladas de emergencias extrahospitalarias atendidas por personas legas en primeros auxilios. La tesis se estructura en tres secciones: a) Usabilidad, b) Videoasistencia con smart glasses en emergencias extrahospitalarias y c) Entrenamiento en RCP con realidad aumentada. Cada sección tiene sus objetivos específicos respectivos: a) evaluar la viabilidad de la comunicación a través de videollamadas utilizando smart glasses en un entorno extrahospitalario para determinar su aplicabilidad en un escenario simulado de paro cardíaco atendido por legos, b) evaluar el impacto de utilizar smart glasses para la comunicación por video con el teleoperador de emergencias en el desempeño de los testigos en situaciones simuladas de emergencias extrahospitalarias, con un enfoque en el cumplimiento del protocolo de actuación y la mejora de la calidad de las técnicas de asistencia en tales emergencias, y c) analizar la teleformación con realidad aumentada a través de smart glasses como herramienta educativa para el manejo de paros cardíacos.

MATERIAL Y MÉTODOS. La **metodología** de la tesis doctoral comprendió seis estudios: tres estudios piloto cuasiexperimentales aleatorizados, un estudio descriptivo y comparativo, una carta al editor, y un estudio preexperimental de un solo grupo con preprueba y posprueba. Todos los estudios se adhirieron a los principios de la Declaración de Helsinki y fueron aprobados por los respectivos Comités de Ética. Se obtuvo el consentimiento informado de todos los participantes. En todos los estudios, los participantes recibieron una breve capacitación (menos de 5 minutos) para familiarizarse con las funciones básicas de las smart glasses, que estaban conectadas a través de una red inalámbrica 4G y equipadas con la aplicación Vuzix Remote Assist.

Se llevaron a cabo simulaciones en entornos realistas, que incluían escenarios como un barco, una playa y un aula universitaria. Los participantes participaron en simulaciones de emergencias extrahospitalarias en las que debían actuar extrahospitalarias o en entrenamientos de SVB. Las simulaciones implicaron el uso de un maniquí de resucitación conectado a diversos equipos, y se recopilaron datos sobre varios parámetros, incluido el cumplimiento del protocolo de RCP, la calidad de las compresiones torácicas, los tiempos de actuación, la autopercepción del desempeño y la facilidad de uso de las smart glasses.

En los estudios relacionados con la videoasistencia del teleoperador, los participantes se comunicaron mediante videollamadas con las smart glasses mientras recibían orientación de un experto en emergencias. Estos grupos se compararon con condiciones de control en las que no había asistencia o había una asistencia telefónica tradicional. En los estudios de formación, los participantes aprendieron con asistencia de video a través de smart glasses en comunicación con un instructor telemático, y su desempeño en escenarios de paro cardíaco extrahospitalario se registró y comparó con grupos de referencia o grupos de control que recibieron enseñanza tradicional presencial. Se realizaron análisis estadísticos utilizando el software IBM SPSS Statistics, que incluyeron estadísticas descriptivas, pruebas t de Student, pruebas de chi-cuadrado, cálculos de tamaño del efecto y pruebas de significación con $p < 0,05$.

RESULTADOS. Los **resultados de la sección de Usabilidad** mostraron que se necesitaba asistencia a través de smart glasses en el 72% de los pasos del SVB, lo que permitió que todos los participantes realizaran el enfoque ABC y utilizaran el DEA correctamente. Se demostró la viabilidad de que la retroalimentación del teleoperador a través de smart glasses ayudara a mejorar el desempeño de los testigos, ya que después de que el teleoperador diera retroalimentación a través de smart glasses, solo el 3% de las habilidades fueron incorrectas. La comparación entre la evaluación en el lugar de los hechos por el investigador y la evaluación a través de smart glasses por el teleoperador difirieron en un 8% de las habilidades analizadas, siendo la mayor diferencia en la "posición incorrecta de las manos durante la RCP" (en la escena: 33% vs. teleoperador: 0%). Al comparar el primer minuto (sin asistencia) con el segundo minuto de RCP (con videoasistencia), solo hubo diferencias significativas en el porcentaje de compresiones con la profundidad correcta (1er: $48 \pm 42\%$, 2do: 70 ± 31 , $p = 0,02$). Por otro lado, los **resultados de la sección de Video-asistencia en emergencias extrahospitalarias** mostraron que nueve de los 14 participantes con smart glasses y asistencia por video (SG-VA) completaron correctamente el protocolo de SVB, en comparación con ninguno de los participantes C que recibieron asistencia por audio a través de un teléfono inteligente (SP-AA) ($p = 0,01$). Un número significativamente mayor de legos de SG-VA abrieron con éxito la vía aérea (13 vs. 5, $p = 0,002$), verificaron la respiración (13 vs. 8, $p = 0,03$), colocaron correctamente los electrodos del DEA (14 vs. 6, $p = 0,001$) y advirtieron a los testigos que se mantuvieran alejados antes de administrar la descarga (12 vs. 0, $p < 0,001$). No se observaron diferencias significativas en los tiempos de actuación ni en la calidad de las compresiones torácicas. La tasa media de compresiones fue de 104 compresiones por minuto en el grupo SG-VA y 98 compresiones por minuto en el grupo SP-AA ($p = 0,46$); la profundidad media de las compresiones fue de 4,5 cm y 4,4 cm ($p = 0,49$), respectivamente. Por su lado, los **resultados de la Video-asistencia para el parto** no planificado muestran que la asistencia de una matrona mediante smart glasses permitió que el 35% de los participantes llevara a cabo el protocolo completo. Ningún participante del grupo C (sin asistencia) pudo llevarlo a cabo ($p = 0,005$). Todas las variables del protocolo fueron significativamente mejores con smart glasses que en el grupo C ($p < 0,05$). La telemedicina a través de la asistencia por video con smart glasses es factible y útil, de manera que un socorrista sin conocimientos ni experiencia previa en la atención al parto puede actuar según las recomendaciones en un parto simulado extrahospitalario no planificado y sin complicaciones. Por último, los **resultados de la sección de realidad aumentada para el entrenamiento de SVB** muestran que después de la formación, todos los participantes fueron capaces de realizar un SVB de buena calidad, con resultados comparables a los obtenidos cuando fueron guiados en tiempo real por el instructor a través de las smart glasses. La tasa media de compresiones torácicas fue significativamente mayor cuando no se les guiaba (113/min vs. 103/min, $p = 0,001$). Cuando no recibieron asistencia, los participantes emplearon menos tiempo en llevar a cabo los pasos secuenciales del SVB que cuando fueron asistidos durante el entrenamiento. Además, al comparar el aprendizaje mediante realidad aumentada con smart glasses con la enseñanza tradicional presencial, en la mayoría de las variables del protocolo del SVB, la calidad de la reanimación y los tiempos de desempeño, no hubo diferencias estadísticamente significativas entre los grupos. Se observaron diferencias significativas (a favor de las smart glasses) en la evaluación de la respiración (smart glasses: 100%, C: 81%; $p=0,013$), la advertencia de no tocar antes de aplicar la descarga del DEA (smart

glasses: 79%, C: 52%; $p=0,025$) y las compresiones con correcta reexpansión (smart glasses: 85%, C: 32%; $p=0,008$).

CONCLUSIONES. Las **conclusiones** de esta tesis doctoral pueden categorizarse en tres secciones, correspondientes a hipótesis específicas abordadas en los diversos artículos incluidos en este compendio de publicaciones. Las conclusiones basadas en cada hipótesis son las siguientes: H1 - C1: Las smart glasses son factibles para situaciones de emergencia fuera del hospital, incluso en entornos desafiantes, con una buena conectividad Wi-Fi. H2a - C2a: La transmisión de video a través de smart glasses mejora la transferencia de información en situaciones de emergencia, mejorando el SVB y DEA sin comprometer la calidad de las compresiones torácicas. H2b - C2b: Las smart glasses permiten la telemedicina en escenarios de parto extrahospitalario no planificado, beneficiando tanto las habilidades técnicas como las no técnicas. H3 - O3: La teleformación con realidad aumentada mediante smart glasses es valiosa para la educación en SVB para legos y puede ser tan efectiva como los métodos tradicionales. En resumen, las smart glasses muestran promesa para mejorar la respuesta en emergencias, la asistencia en el parto y la capacitación en RCP. **En resumen**, las smart glasses ofrecen un gran potencial para mejorar la respuesta en situaciones de emergencias extrahospitalarias atendidas por legos y en comunicación con el teleoperador de emergencias. Además, esta comunicación con este wearable puede abrir nuevas posibilidades como herramienta educativa de realidad aumentada para la formación remota en SVB.

2.3 RESUMO

Nota:

Este resumo é unha versión reducida do documento principal redactado segundo a normativa da USC, en lingua inglesa.

As referencias bibliográficas foron citadas no manuscrito en inglés.

INTRODUCCIÓN. A incidencia global e o prognóstico do paro cardiorrespiratorio extrahospitalario (PCEH) varían de forma significativa en todo o mundo. Segundo o estudo EuReCa-TWO, a incidencia global da PCR extrahospitalaria (PCEH) na que se intentou levar a cabo a reanimación cardiopulmonar (RCP) é de 56 casos por cada 100.000 habitantes ao ano (intervalo: 21–91). Este estudo prospectivo, que analiza datos de 28 cidades europeas, revela que as accións das testemuñas desempeñan un papel crucial. As accións das testemuñas xogan un papel crucial á hora de influír na supervivencia e os resultados das vítimas de PCEH porque cando inician RCP antes da chegada dos servizos de emerxencia médicos (SEM), a taxa de supervivencia é dúas veces maior ca cando a inician os SEM. Desafortunadamente, as persoas que poderían axudar en tales emerxencias poden carecer dos coñecementos, actitudes e habilidades de soporte vital básico (SVB) necesarios, o que leva a que ata o 65% dos PCEH queden sen atención até a chegada da ambulancia. A intervención dos espectadores tamén é vital noutras emerxencias extrahospitalarias, coma os partos non planificados, que poden ser un desafío cando ocorren lonxe dos centros de atención médica ou de súpeto en mulleres múltiparas. En países avanzados, o parto fóra do hospital non planificado e sen a asistencia de matronas é un evento moi raro (0,07% en España), que xeralmente ocorre porque a embarazada está lonxe do centro de saúde ou se desencadea repentinamente en mulleres múltiparas. Aínda que se estima que a prevalencia mundial dos partos non planificados fóra do hospital é do 0,19 - 0,61%, o seu número absoluto é moi alto. Deles, o 35% ocorre sen atención médica e é atendido por familiares ou testemuñas (o 14% son atendidos por unha soa persoa).

Recoñecendo o papel fundamental da intervención de testemuñas nas emerxencias, o Consello Europeo de Reanimación (ERC, polas súas siglas en inglés) desenvolveu estratexias para mellorar a resposta. Isto inclúe capacitar aos teleoperadores de SEM para prestar asistencia telefónica e educar á poboación para mellorar a preparación en situacións de emerxencia. Estes esforzos teñen como obxectivo fortalecer e optimizar a resposta ós eventos críticos, cun enfoque en estratexias relacionadas coa reanimación, pero tamén aplicables a outras emerxencias extrahospitalarias. As directrices do ERC salientan as respostas comunitarias e a capacitación dos teleoperadores de SEM para prestar asistencia telefónica para SVB e RCP de alta calidade. Con todo, a asistencia telefónica ten limitacións debido a que depende da comunicación verbal, que non sempre cumpre cos estándares esperados. Os desafíos que afrontan os teleoperadores inclúen dificultades para avaliar a respiración da vítima e problemas para activar a función de activar os altofalantes dos mans libres do teléfono intelixente.

Os avances tecnolóxicos recentes introduciron videochamadas en smartphones, o que amosa beneficios potenciais para mellorar as taxas de resposta e a calidade do SVB. Tamén se explorou a comunicación asistida por vídeo con smart glasses, que ofrece unha asistencia en base á visión do escenario pola cámara frontal do dispositivo que leva a persoa no seu corpo. Aínda que é

prometedor, pode ter inconvenientes, como posibles retrasos nos tempos de actuación e a necesidade de que unha segunda persoa sosteña e encadre o teléfono intelixente durante as videochamadas.

A segunda estratexia do ERC implica educar á poboación en SVB para garantir respostas efectivas a PCEH e outras emerxencias. Nos últimos anos, dada a relación establecida entre a calidade da RCP e o resultado da PCEH, foron propostos varios programas educativos en soporte vital básico adaptados para persoas non profesionais sen coñecemento previo de primeiros auxilios (legos). Estes programas amosan unha variabilidade significativa en canto á súa duración, frecuencia, contexto e o uso de tecnoloxías de comunicación. Mentres que os programas tradicionais de capacitación en soporte vital básico realizábanse de forma predominante presencial, caracterizándose pola súa longa duración e programación pouco frecuente, evolucionaron co tempo para adoptar formatos máis curtos e frecuentes, coa súa efectividade demostrada. Incluso programas moi breves, que requiren menos de 10 minutos, demostraron ser valiosos para mellorar as respostas ante PCEH, aumentando o número de persoas capacitadas na mesma unidade de tempo en comparación cos métodos tradicionais máis longos.

Na actualidade, grazas aos avances tecnolóxicos, a innovación en situacións de emerxencia alcanzou un potencial case ilimitado. Un avance tecnolóxico destacado é a integración da realidade aumentada (RA) con smart glasses para a comunicación en situacións de emerxencia fóra do hospital. A RA demostrou a súa eficacia en diversos campos, incluíndo a atención médica e a educación. Esta comunicación permite aos usuarios ver información dixital en tempo real no mundo físico, o que pode ser útil para recibir instrucións dun tele-operador de emerxencias ou para aprender técnicas para a atención do paciente crítico. O aumento na dispoñibilidade de dispositivos de RA, como as smart glasses, xerou interese na súa aplicación en situacións de emerxencia, especialmente na formación e no rendemento de persoas non profesionais (lexos). Esta innovadora forma de comunicación podería revolucionar a resposta das testemuñas en situacións críticas ao ofrecer axuda en tempo real ou facilitar a capacitación mediante a RA.

OBXECTIVOS. Tendo en conta todo o mencionado anteriormente, o obxectivo xeral desta tese foi avaliar a viabilidade de empregar a realidade aumentada con intercomunicación asistida por vídeo a través de smart glasses e analizar as melloras que aporta no desempeño e a formación durante situacións simuladas de emerxencias extrahospitalarias atendidas por persoas sen experiencia en primeiros auxilios. A tese estrutúrase en tres seccións: a) Usabilidade, b) Videoasistencia con smart glasses en emerxencias extrahospitalarias e c) Adestramento en RCP con AR. Cada sección ten os seus obxectivos específicos respectivos: a) avaliar a viabilidade da comunicación a través de videochamadas utilizando smart glasses nun entorno extrahospitalario para determinar a súa aplicabilidade nun escenario simulado de paro cardíaco atendido por legos (*que se compoñen de 2 obxectivos máis específicos: Analizar a viabilidade da intercomunicación mediante smart glasses entre un tele-operador e unha testemuña pescador non profesional durante a atención básica á vida mentres navega nunha pequena embarcación / Analizar a secuencia do enfoque ABC, o uso do DEA e os pasos correctos das habilidades de RCP realizadas por pescadores asistidos coa innovadora ferramenta das smart glasses*), b) avaliar o impacto de utilizar smart glasses para a comunicación por vídeo co teleoperador de emerxencias no desempeño dos testemuñas en situacións simuladas de emerxencias

extrahospitalarias, cun enfoque no cumprimento do protocolo de actuación e a mellora da calidade das técnicas de asistencia nestas emerxencias (*que se compoñen de 2 obxectivos máis específicos: Avaliar se a asistencia do tele-operador mediante smart glasses mellora o rendemento da testemuña na SVB durante unha simulación de PCEH en comparación coa instrución telefónica soa / Avaliar as posibles vantaxes da tele-axuda guiada pola matrona usando a comunicación de vídeo de realidade aumentada con smart glasses para o manexo dun parto eutócico non planificado fóra do hospita*), e c) analizar a teleformación con RA a través de smart glasses como ferramenta educativa para o manexo de paros cardíacos (*que se compoñen de 3 obxectivos máis específicos: Analizar o posible impacto na aprendizaxe de SVB dun adestramento moi breve baseado na experiencia dunha actuación nun paro cardíaco simulado e co apoio da comunicación por vídeo das smart glasses en persoas non profesionais / Analizar a eficacia dunha metodoloxía de ensino-aprendizaxe de tele-formación en SVB baseada na comunicación a través de smart glasses e comparala cun programa de formación tradicional en persoa / Avaliar a viabilidade de enviar imaxes animadas ás lentes das smart glasses no proceso de ensino de SVB*).

MATERIAL E MÉTODO. A **metodoloxía** da tese de doutoramento comprendeu cinco estudos: tres estudos piloto cuasiexperimentais aleatorizados, un estudo descritivo e comparativo, unha carta ao editor, e un estudo preexperimental de un só grupo con preproba e posproba. Todos os estudos adheríronse aos principios da Declaración de Helsinki e foron aprobados polo Comité de Ética de Investigación Clínica do Consello Catalán de Deportes. Obtívose o consentimento informado de tódolos participantes. En tódolos estudos, os participantes recibiron unha breve formación (menos de 5 minutos) para familiarizarse coas funcións básicas das smart glasses relacionadas coa comunicación mediante video chamada. As smart glasses estaban conectadas a través dunha rede sen fíos 4G e equipadas coa aplicación Vuzix Remote Assist (VRA App) que permite realizar video chamadas a outro dispositivo, como a un ordenador. Nestes estudos, a video chamada realizouse a un ordenador portátil conectado á páxina web da aplicación (<https://vra.vuzix.com>) que manexaba o tele operador ou o instrutor. Leváronse a cabo simulacións en arredores realistas, que incluían escenarios como un bote, unha praia e unha aula universitaria. Os participantes participaron en simulacións de emerxencias extrahospitalarias nas que debían actuar ou adestrar. As simulacións implicaron o uso dun manequín de resucitación conectado a diversos equipos, e recompiláronse datos sobre varios parámetros, incluído o cumprimento do protocolo de RCP, a calidade das compresións torácicas, os tempos de actuación, a autopercepción do desempeño e a facilidade de uso das smart glasses. Nos estudos relacionados coa videoasistencia do teleoperador, os participantes comunicáronse mediante videochamadas coas smart glasses namentres recibían orientación dun experto en emerxencias. Nos estudos nos que houbo unha simulación dunha parada cardiorrespiratoria, o tele operador era un instrutor acreditado polo Consello Europeo de Reanimación (ERC, polas súas siglas en inglés). No estudo no que houbo unha simulación dun parto extra hospitalario non planificado, a tele operadora foi unha matrona experta na atención do parto. Estes grupos comparáronse con condicións de control nas que non había asistencia ou había unha asistencia telefónica tradicional. Nos estudos de formación, os participantes aprenderon con asistencia de vídeo a través de smart glasses en comunicación cun instrutor telemático, e o seu desempeño en escenarios de paro cardíaco extrahospitalario avaiouse, rexistrouse e comparouse con grupos de referencia ou grupos de control que recibiron ensinanza tradicional presencial. En todos os

estudos rexistráronse variables socio-demográficas (idade, peso, altura) para a descrición da mostra. Nos estudos de simulación de parada cardiorrespiratoria avalíouse o protocolo de actuación do soporte vital básico de forma dicotómica (como realizado correctamente ou incorrectamente). Tamén se incluíron aspectos relacionados co manexo do DEA (colocación correcta dos electrodos, avisar que ninguén toque á vítima durante a descarga do DEA...). Ademais, rexistrouse a calidade da reanimación cardiopulmonar avaliada cunha App (CPR instructor, Laerdal, Noruega) conectada a un manequín de prácticas (Little Anne QCPR manikin, Laerdal, Noruega). Da calidade da reanimación avaliáronse principalmente parámetros relacionados coa calidade das compresións torácicas (ritmo de compresión, profundidade de compresión, compresións torácicas realizadas no punto de compresión axeitado...). Tamén se cronometraron os tempos de actuación, incluíndo o tempo transcorrido até o inicio da primeira compresión torácica ou a desfibrilación do DEA. No estudo sobre simulación de parto extra-hospitalario non planificado foi con un simulador materno-fetal (PROMPT Flex, Laerdal, Noruega) manexado por unha matrona experta en partos. Avaliou de modo dicotómico o protocolo de actuación seguindo as recomendacións das guías de práctica clínica para este tipo de parto sen complicacións (anotábase se realizaban correctamente ou non as diferentes habilidades técnicas e non técnicas do protocolo de actuación). Tanto nos escenarios de simulación de parada cardiorrespiratoria como no escenario de simulación do parto extra hospitalario non planificado, avaliáronse variables perceptivas en escalas do 0 ao 10. Por unha banda, sobre a facilidade no manexo das smart glasses (onde 0 quería dicir que eran moi fáciles de manexar e 10 era moi difíciles); e por outra banda, sobre a súa percepción da actuación e confianza para actuar nun caso real. Ademais, nos estudos nos que se proxectaron imaxes ou imaxes animadas (GIFs) nas lentes das smart glasses, tamén se preguntou a opinión do participante sobre en que medida consideraba que esa asistencia visual lle axudara na súa actuación (onde 0 quería dicir que non lle axudara nada e 10 que lle axudara moito).

Realizáronse análises estatísticas utilizando o software IBM SPSS Statistics (v.20.Windows, Armonk, NY: IBM Corp). As variables categóricas describíronse a través de frecuencias absolutas e relativas, mentres que as variables continuas describíronse mediante medidas de tendencia central (media ou mediana) e dispersión (desviación estándar ou rango intercuartílico). As comparacións entre grupos realizáronse utilizando a proba t (ou a proba de rangos para variables non distribuídas normalmente). As variables cualitativas dos protocolos de actuación comparáronse utilizando a proba de Chi-cadrado. Medíronse os tamaños de efecto para variables cuntes con diferenzas significativas utilizando a proba de Cohen's d (ou a proba de Rosenthal's r para variables non distribuídas normalmente). Clasificáronse como triviais ($< 0,2$), pequenos ($0,2 - 0,5$), moderados ($0,5 - 0,8$), grandes ($0,8 - 1,3$) ou moi grandes ($\geq 1,3$). Utilizouse a proba de Cramer V para calcular os tamaños de efecto das variables cualitativas, clasificándoos como pequenos ($0,1 - 0,3$), medianos ($0,3 - 0,5$) ou grandes ($\geq 0,5$). A significación estableceuse na $p < 0,05$.

RESULTADOS. Os resultados da sección de Usabilidade mostraron que era necesaria a axuda a través de smart glasses no 72% dos pasos do SVB, o que permitiu a tódolos participantes realizar o enfoque ABC e utilizar o DEA correctamente. Demostrouse a viabilidade de que o feedback do tele-operador a través de smart glasses axudara a mellorar o desempeño dos testemuñas, xa que despois de que o tele-operador deu feedback a través de smart glasses, só o 3% das habilidades foron incorrectas. A comparación entre a avaliación no lugar dos feitos polo

investigador e a avaliación a través de smart glasses polo teleoperador diferiu nun 8% das habilidades analizadas, sendo a maior diferenza na "posición incorrecta das mans durante a RCP" (na escena: 33% vs. teleoperador: 0%). Ao comparar o primeiro minuto (sen asistencia) co segundo minuto de RCP (con videoasistencia), só houbo diferenzas significativas no porcentaxe de compresións coa profundidade correcta (1º: 48 ± 42 %, 2º: 70 ± 31 , $p = 0,02$). Por outra banda, **os resultados da sección de Video-asistencia** en emerxencias extra-hospitalarias para a atención da parada cardiorrespiratoria mostraron que nove dos 14 participantes con smart glasses e asistencia por vídeo (SG-VA) completaron correctamente o protocolo de SVB, en comparación con ningunha dos participantes C que recibiron asistencia por audio a través dun teléfono intelixente (SP-AA) ($p = 0,01$). Un número significativamente maior de legos de SG-VA abriron con éxito a vía aérea (13 vs. 5, $p = 0,002$), verificaron a respiración (13 vs. 8, $p = 0,03$), colocaron correctamente os electrodos do DEA (14 vs. 6, $p = 0,001$) e avisaron aos testemuñas que se mantiveran afastados antes de administrar a descarga (12 vs. 0, $p < 0,001$). Non se observaron diferenzas significativas nos tempos de actuación nin na calidade das compresións torácicas. A taxa media de compresións foi de 104 compresións por minuto no grupo SG-VA e 98 compresións por minuto no grupo SP-AA ($p = 0,46$); a profundidade media das compresións foi de 4,5 cm e 4,4 cm ($p = 0,49$), respectivamente. Polo seu lado, **os resultados da Video-asistencia para o parto** non planificado mostraron que a asistencia dunha matrona mediante smart glasses permitiu que o 35% dos participantes levaran a cabo o protocolo completo. Ningunha participante do grupo C (sen asistencia) puido levalo a cabo ($p = 0,005$). Todas as variables do protocolo foron mellores de forma significativa con smart glasses que no grupo C ($p < 0,05$). A telemedicina a través da asistencia por vídeo con smart glasses é factible e útil, de maneira que un socorrista sen coñecementos nin experiencia previa na atención ao parto pode actuar segundo as recomendacións nun parto simulado extrahospitalario non planificado e sen complicacións.

Por último, **os resultados da sección de RA para o adestramento de SVB** mostraron que despois da formación, todos os participantes foron capaces de realizar un SVB de boa calidade, con resultados comparables aos obtidos cando foron guiados en tempo real polo instructor a través das smart glasses. A taxa media de compresións torácicas foi significativamente maior cando non se lles guiaba (113 / min vs. 103 / min, $p = 0,001$). Cando non recibiron asistencia, os participantes empregaron menos tempo en levar a cabo os pasos secuenciais do SVB que cando foron asistidos durante o adestramento. Ademais, ao comparar a aprendizaxe mediante RA con smart glasses coa ensinanza tradicional presencial, na maioría das variables do protocolo do SVB, a calidade da reanimación e os tempos de desempeño, non houbo diferenzas estatisticamente significativas entre os grupos. Observáronse diferenzas significativas (a favor das smart glasses) na avaliación da respiración (smart glasses: 100 %, C: 81 %; $p = 0,013$), o aviso de non tocar antes de aplicar a descarga do DEA (smart glasses: 79 %, C: 52%; $p = 0,025$) e as compresións con correcta reexpansión (smart glasses: 85 %, C: 32 %; $p = 0,008$).

CONCLUSIÓNS. As **conclusións** desta tese de doutoramento pódense categorizar en tres seccións, correspondentes a hipóteses específicas abordadas nos diversos artigos incluídos neste compendio de publicacións. As conclusións baseadas en cada hipótese son as seguintes: H1 - O1: As smart glasses son factibles para situacións de emerxencia fóra do hospital, mesmo en entornos desafiantes, cunha boa conectividade Wi-Fi. H2a - O2a: A transmisión de vídeo a través de smart glasses mellora a transferencia de información en situacións de emerxencia,

mellorando o SVB e DEA sen comprometer a calidade das compresións torácicas. H2b - O2b: As smart glasses permiten a telemedicina en escenarios de parto extrahospitalario non planificado, beneficiando tanto as habilidades técnicas como as non técnicas. H3 - O3: A teleformación con AR a través de smart glasses é valiosa para a educación en SVB para legos e pode ser tan efectiva como os métodos tradicionais. En resumo, as smart glasses agoiran mellorar a resposta en emerxencias, a asistencia no parto e a formación en RCP. **Resumindo**, as smart glasses ofrecen un gran potencial para mellorar a resposta en situacións de emerxencias fóra do hospital atendidas por legos e en comunicación co teleoperador de emerxencias. Ademais, esta comunicación con este dispositivo pode abrir novas posibilidades como ferramenta educativa de RA para a formación remota en SVB.

3.INTRODUCTION

3 INTRODUCTION

3.1 INCIDENCE OF OUT-OF-HOSPITAL CARDIORESPIRATORY ARREST (OHCA) AND UNPLANNED CHILDBIRTH, AND THE ROLE OF BYSTANDERS

The global incidence and outcome of out-of-hospital cardiorespiratory arrest (OHCA) exhibit significant variability worldwide [1]. According to EuReCa-TWO study, the overall incidence of OHCA where cardiopulmonary resuscitation (CPR) was attempted is 56/100,000 population/year (range: 21–91) [2]. This prospective study, which analyzes data from 28 European cities, reveals that CPR was started before the arrival of emergency medical services in 58% of the cases, and the survival rate was twice as high when CPR was started by a bystander compared to when it was initiated by emergency medical services [2]. In the context of an OHCA, the actions of bystanders are paramount factors influencing the survival and ultimate outcomes of the victim [2–4]. Regrettably, individuals who are in a position to assist may not always possess the requisite knowledge, attitudes, and basic life support (BLS) skills, resulting in up to 65% of prehospital cardiac arrest events remaining unattended until the arrival of an ambulance [2,5].

Furthermore, bystander intervention can also be crucial in other types of out-of-hospital emergencies while the ambulance is coming. An example would be an unplanned childbirth. In advanced countries, unplanned and unattended by midwives out-of-hospital child birth is a very rare event (0.07% in Spain) [6], which usually occurs because the pregnant is far from the health center or it is triggered suddenly in multiparous women [7–9]. Although the worldwide prevalence of unplanned out-of-hospital births is estimated to be 0.19-0.61% [10,11], their absolute number is very high. Of them, 35% occur without medical care and are attended by family members or witnesses (14% by a single person) [9]. Similarly to other emergencies, the layperson may be assisted by telephone through the emergency center [12,13], as occurred in some out-of-hospital births (12.5%) [9]. Ideally, the assistance should be carried out by a midwife, who is the specialist in childbearing women's care [14,15].

In both cases, whether it's a cardiac arrest or an unplanned childbirth, rescuers share the need to follow a protocol of action and apply specific techniques to improve the outcome of the emergency.

3.2 STRATEGIES TO IMPROVE BYSTANDER RESPONSE IN OUT-OF-HOSPITAL EMERGENCIES: DISPATCHER AND BYSTANDERS' TRAINING

Recognizing the paramount importance of bystander intervention in emergency situations, the European Resuscitation Council (ERC) has devised multiple strategies to bolster an efficient response. Notably, a dual-pronged approach has emerged, encompassing the following components: a) augmenting the training of emergency service dispatchers to enhance the provision of telephonic assistance to laypersons, and b) imparting education to the public to elevate citizens' readiness to act in emergency circumstances. These initiatives collectively represent a deliberate endeavor by the ERC to fortify and optimize the response to critical events affecting the populace, with a primary focus on resuscitation-related strategies, though they are applicable to a wide range of out-of-hospital emergencies (Figure 3-1).

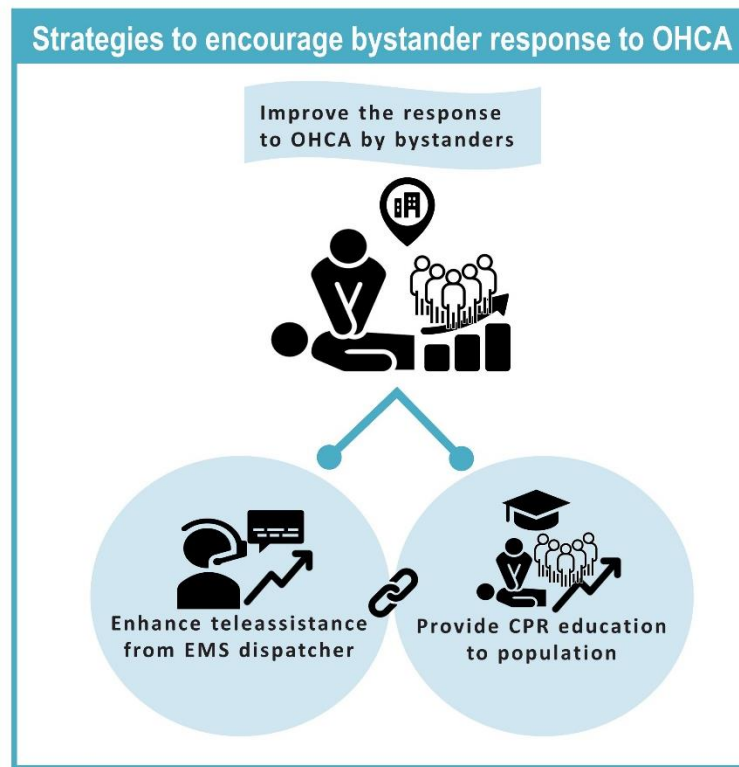


Figure 3-1. Diagram of the two strategies to encourage bystander response to out-of-hospital cardiac arrest. (Author-created figure)

To encourage active involvement of lay bystanders and enhance their performance in emergency situations, ERC guidelines emphasize the importance of community response, including access to semi-automatic defibrillators (AEDs) and training emergency service dispatchers to provide telephone assistance in the basic life support (BLS) sequence and the delivery of high-quality cardiopulmonary resuscitation (CPR) [3]. However, it is relevant to note that when providing this assistance via telephone, the information is limited to verbal communication, which has been associated with practical outcomes that do not always meet the expected standards [16,17]. Despite the doubling of bystander response rates [18], emergency dispatchers still face significant challenges. For instance, approximately 30% of OHCA encounter difficulties in assessing the victim's normal breathing [19]. This may stem from contradictory information provided by the rescuer or the declaration that they cannot or do not know how to assess the patient [18]. Furthermore, 37% of bystanders are unable to activate the hands-free speaker function [20], which is the recommended standard [4]. Consequently, this hinders the early initiation of chest compressions with continuous telephone assistance.

3.3 CHALLENGES AND OPPORTUNITIES IN BYSTANDER ASSISTANCE AND THE NEED FOR IMPROVEMENT

Contemporary technology allows for video calls to be conducted on smartphones, and it has been demonstrated, under simulated conditions, that this can be beneficial in improving response rates and certain parameters related to the quality of BLS [12]. It has also been

observed that this feature can enhance survival rates and mitigate neurological damage in real victims [21]. These advantages primarily arise from the teleoperator's ability to not only hear but also visually assess the situation, its location, and the actions being performed. However, it is worth noting that the authors themselves have reservations about video call teleassistance with a smartphone, as it has the potential to delay the initiation of resuscitation efforts [12] and is not feasible with a single bystander (since someone must hold the smartphone and frame the image) [21].

On the other hand, as the second strategic line of action outlined by the ERC related to public education aimed at enhancing the number of trained citizens, the ERC recommends training in BLS [22]. This is intended to ensure that any citizen can effectively respond to an OHCA, thus promoting higher survival rates for the victim [23]. The BLS sequence includes recognizing OHCA, alerting emergency services, using the semi-automatic external defibrillator (AED), and performing high-quality cardiopulmonary resuscitation (CPR) [4] (Figure 3-2). In the case of responding to an unplanned childbirth, the protocol of action includes a sequence of steps involving technical and non-technical skills for the care of both the mother and the baby during the various stages of childbirth

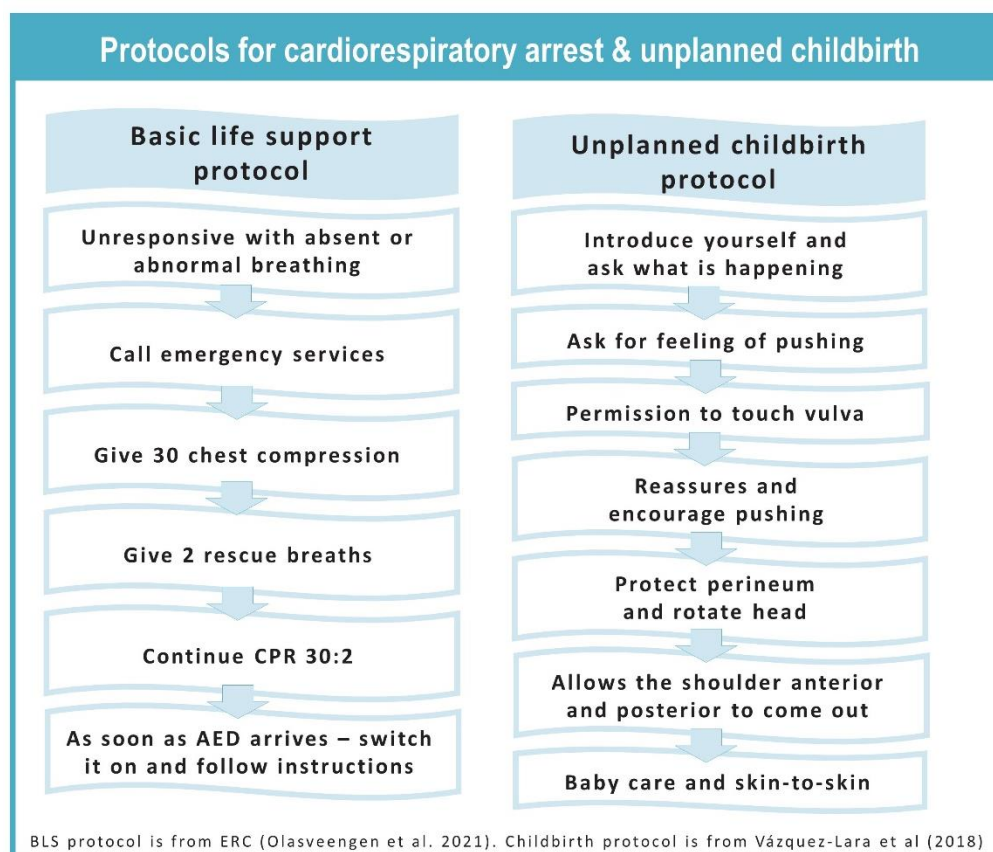


Figure 3-2. European Resuscitation Council action protocol for out-of-hospital cardiorespiratory arrest and protocol for out-of-hospital unplanned childbirth (Author-created figure based on Olasveengen et al 2021 and Vázquez-Lara et al 2018)

In recent years, given the established relationship between the quality of CPR and the outcome of OHCA [3], various educational programs in basic life support (BLS) tailored to laypeople have been proposed. These programs exhibit significant variability in terms of their duration, frequency, context, and the use of communication technologies. While traditional BLS training programs were predominantly conducted in-person, characterized by lengthy duration and infrequent scheduling, they have evolved over time to adopt shorter and more frequent formats, with demonstrated effectiveness [24–26]. Even very brief programs, requiring less than 10 minutes, have proven valuable in improving responses to OHCA, increasing the number of individuals trained within the same unit of time compared to traditional methods [27].

3.4 THE POTENTIAL OF SMART GLASSES IN OUT-OF-HOSPITAL EMERGENCIES RESPONSE

In the current era, characterized by rapid technological advancements, the potential for innovation in the field of emergencies has become virtually limitless. One of the technological advances that stands out for its immense potential in out-of-hospital emergency situations is the integration of augmented reality (AR) with video-assisted intercommunication through smart glasses. AR has demonstrated a high degree of effectiveness in various fields, including healthcare and education [28,29]. This type of communication enables users to experience real-time immersive overlays of digital information in the physical world, which may encompass data provided by an emergency dispatcher or guidance from an expert for training or learning in cardiopulmonary resuscitation [30]. The proliferation of AR devices in recent years, such as smart glasses, has generated growing interest in exploring their feasibility and potential benefits [31]. It is precisely in the realm of training and the performance of laypeople during out-of-hospital emergencies where this form of communication with smart glasses could have a significant and worthy impact to investigate. This innovative communication approach could represent a unique opportunity to revolutionize how bystanders respond to critical situations, whether by receiving real-time assistance from an emergency dispatcher or by learning skills through AR. Therefore, it could be interesting to consider conducting comprehensive studies to assess the feasibility and potential usefulness of this technology in addressing out-of-hospital emergencies attended by laypeople.

The use of smart glasses, which enable high-quality and straightforward video calls without the need to handle a smartphone [32], could address the inherent drawbacks of video call communication via smartphones and, consequently, enhance the effectiveness of teleoperated BLS). This form of communication has already been employed within hospital settings, such as during surgical procedures [33], although its utilization in out-of-hospital contexts has been limited, up to the time of this thesis, primarily to victim triage [32]. Smart glasses, representing a novel category of wearable communication technology, which, while not yet ubiquitous among the general population, is anticipated to become widespread in the coming years, similar to the proliferation experienced by smartphones in the past. Currently, there is no doubt about the recommendation to use smartphone speaker-assisted assistance to enhance dispatcher-assisted CPR [3]. This recommendation was unimaginable prior to its inclusion in the 2010 guidelines by the American Heart Association [34], even though 35 years had passed since the first documented case of telephone-assisted CPR [35]. Furthermore, the pricing of these smart glasses, which are already available in the market (and more affordable than high-end smartphones), could make it possible for untrained bystanders to have this communication

option with dispatchers for addressing various types of out-of-hospital emergencies until the ambulance arrives.

The incorporation of smart glasses technology in emergency assistance not only represents an advancement in the effectiveness of initial response to OHCA or other kinds of emergencies such as an unplanned childbirth, but also opens new perspectives in the realm of BLS training. In addition to their utility in real-time care, the use of smart glasses could offer significant advantages in the process of learning BLS protocol and techniques. These glasses, by providing an immersive, AR, and real-time visual experience, could serve as an effective tool for training the population in BLS, thereby enhancing citizens' preparedness to confidently and competently respond to critical emergencies, such as cardiac arrest or childbirth.

In the latest European Resuscitation Council guidelines, it is advised to harness technology to enhance education in resuscitation and engage a broader audience of learners [22]. The utilization of technology in BLS training programs can offer significant benefits, such as improving the learning process through real-time feedback systems [36], reating more engaging learning experiences, and making education accessible to remote locations through online training [30,37,38]. Among the innovative communication technologies used in education are smart glasses. Communication between students and instructors via video calls using smart glasses has been applied in hospital settings to provide visual assistance to surgeons during operations or to demonstrate surgical procedures in educational contexts [33,39]. However, it remains to be determined whether this type of communication using smart glasses would be beneficial for teaching BLS to non-health professionals. The implementation of a BLS training program using smart glasses, where students and instructors communicate through these wearable devices, could prove valuable in the teaching and learning process of BLS for laypeople.

4. HYPOTHESES AND OBJECTIVES

4 HYPOTHESES AND OBJECTIVES

4.1 GENERAL HYPOTHESES AND OBJECTIVES

4.1.1 General hypothesis

The general hypothesis was that the utilization of augmented reality with video-assisted intercommunication via smart glasses could be both feasible and valuable for improving assistance and training in simulated out-of-hospital emergencies involving laypeople (Figure 4-1).

4.1.2 General Objective

The general objective was to evaluate the feasibility of employing augmented reality with video-assisted intercommunication via smart glasses and analyze the enhancements it contributes to performance and training during simulated out-of-hospital emergencies attended by laypeople.

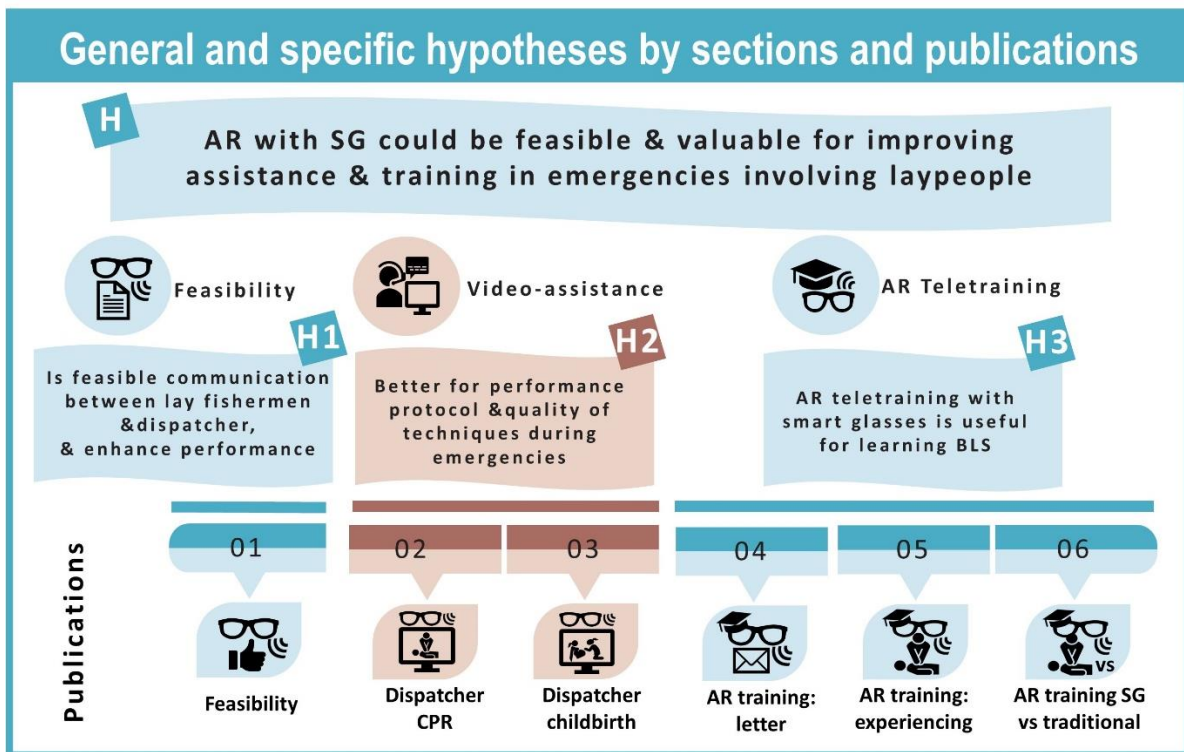


Figure 4-1. Diagram of the general thesis hypothesis and the specific hypotheses for each of the three sections (Feasibility, Video-assistance, and AR Teletraining) and their relationship with the six publications of the thesis. (Author-created figure)

4.2 HYPOTHESES AND SPECIFIC OBJECTIVES BY SECTIONS AND ARTICLES

The specific hypotheses and objectives are detailed below for each of the three sections (feasibility, video-assistance in emergencies, and AR teletraining in BLS) and for each of the six publications that make up the thesis publication compendium.

4.2.1 H1-O1. Feasibility (Article 01)

Below, we introduce the Specific Hypothesis of Section 1 (H1) followed by the Specific Objective of Section 1 (O1). Subsequently, we present the hypotheses and objectives for the Article within this section: 01-Feasibility.

- **H1:** Communication via video call using smart glasses is feasible for the emergency dispatcher and the lay bystander to communicate and also to enhance their performance during a simulated cardiac arrest.

- **H1 - Article 01 – Feasibility**
 - Intercommunication between the emergency dispatcher and a lay bystander in BLS while navigating on a small fishing boat can be feasible through video calls using smart glasses.
 - Intercommunication with smart glasses will facilitate effective performance during a simulated cardiac arrest situation on a navigating boat. Specifically, it will impact the execution of the BLS protocol, the use of AED, and the quality of CPR

- **O1:** To assess the feasibility of communication through videocalls using smart glasses in an out-of-hospital setting to determine its applicability in a simulated cardiac arrest scenario managed by laypersons.

- **O1 - Article 01 – Feasibility**
 - To analyze the feasibility of intercommunication using smart glasses between a teleoperator and a lay fishermen witness during basic life support while navigating on a small boat.
 - To analyze the sequence of the ABC approach, the use of AED, and the correct steps of the CPR skills performed by fishermen who are assisted using the smart glasses innovative tool.

4.2.2 H2-O2. Video-assistance in out-of-hospital emergencies (Articles 02 and 03)

Below, we introduce the Specific Hypothesis of Section 2 (H2) followed by the Specific Objective of Section 2 (O2). Subsequently, we present the hypotheses and objectives for the Articles within this section: 02-Teleassistance in BLS, y 03-Teleassistance in a childbirth.

- **H2:** Communication with the emergency dispatcher through video calls using smart glasses will improve the performance of bystanders in simulated out-of-hospital

emergencies, enhancing both adherence to the action protocol and the quality of assistance techniques in such situations.

- **H2 - Article 02** – BLS teleassistance:
 - "The communication with the emergency dispatcher through video calls using smart glasses will enhance the performance of the bystander compared to standard telephonic assistance, both in terms of adherence to the BLS protocol and the quality of CPR."
- **H2 - Article 03** – Childbirth teleassistance:
 - Interactive guidance by a midwife visualizing in real time what a layperson transmits to him/her through smart glasses will allow this person to perform the appropriate procedures in a simulated and uncomplicated childbirth.
- **O2:** To assess the impact of utilizing smart glasses for video communication with the emergency dispatcher on the performance of bystanders in simulated out-of-hospital emergency situations, with a focus on protocol adherence and the enhancement of assistance techniques' quality in such emergencies.
- **O2 - Article 02** – BLS teleassistance:
 - To evaluate whether dispatcher assistance using smart glasses improves bystander performance in BLS during a simulated OHCA when compared to telephone instruction alone.
- **O2 - Article 03** – Childbirth teleassistance:
 - To assess the potential advantages of midwife-guided teleassistance using augmented reality video communication with smart glasses for the management of an unplanned out-of-hospital eutocic childbirth.

4.2.3 H3-O3. BLS Training with AR (Articles 04, 05 and 06)

Below, we introduce the Specific Hypothesis of Section 3 (H3) followed by the Specific Objective of Section 3 (O3). Subsequently, we present the hypotheses and objectives for the Articles within this section: 04-AR CPR training (letter to editor), 05- Teletraining experiencing a BLS simulation, y 06-BLS teletraining: Smart Glasses vs traditional.

- **H3:** Augmented reality teletraining via video call using smart glasses can serve as a valuable educational tool for learning BLS.
- **H3 - Article 04 (letter to editor)** – AR CPR training:

- The scientific community may find it interesting to know that augmented reality training with smart glasses can be useful for learning BLS.
- **H3 - Article 05** – Teletraining experiencing a BLS simulation:
 - An untrained bystander in BLS is capable of learning the performance protocol and achieving a certain level of CPR quality after experiencing teleassisted guidance through video calls with smart glasses.
- **H3 – Article 06** – BLS teletraining: Smart Glasses vs traditional:
 - A teletraining teaching-learning methodology in BLS using augmented reality and communication via smart glasses can be just as effective as a traditional in-person training approach.
- **O3:** To analyze augmented reality teletraining through smart glasses as an educational tool for cardiac arrest management.
- **O3 - Article 04 (letter to editor)** – AR CPR training:
 - Explain to the scientific community how video call communication with smart glasses can be useful for BLS training.
- **O3 - Article 05** – Teletraining experiencing a BLS simulation:
 - To analyze the potential impact on BLS learning of very brief training based on experiencing a performance in simulated cardiac arrest and with the support of smart glasses video communication in laypersons.
- **O3 - Article 06** – BLS teletraining: Smart Glasses vs traditional:
 - To analyze the effectiveness of a teletraining teaching-learning methodology in BLS based on communication through smart glasses and compare it with a traditional in-person training program.
 - Evaluate the feasibility of sending animated images to the lenses of smart glasses in the BLS teaching process.

5. MATERIALS AND METHODS

5 MATERIAL AND METHODS

Details of the methodology can be found in each article. The most relevant aspects of the methodology of the studies that make up the doctoral thesis are highlighted below.

5.1 DESIGN

Three quasi-experimental randomized pilot studies (Articles 02, 03, 06), one descriptive and comparative study (Article 01), and one single-group pre-posttest pre-experimental (Article 05), were conducted (Figure 5-1).

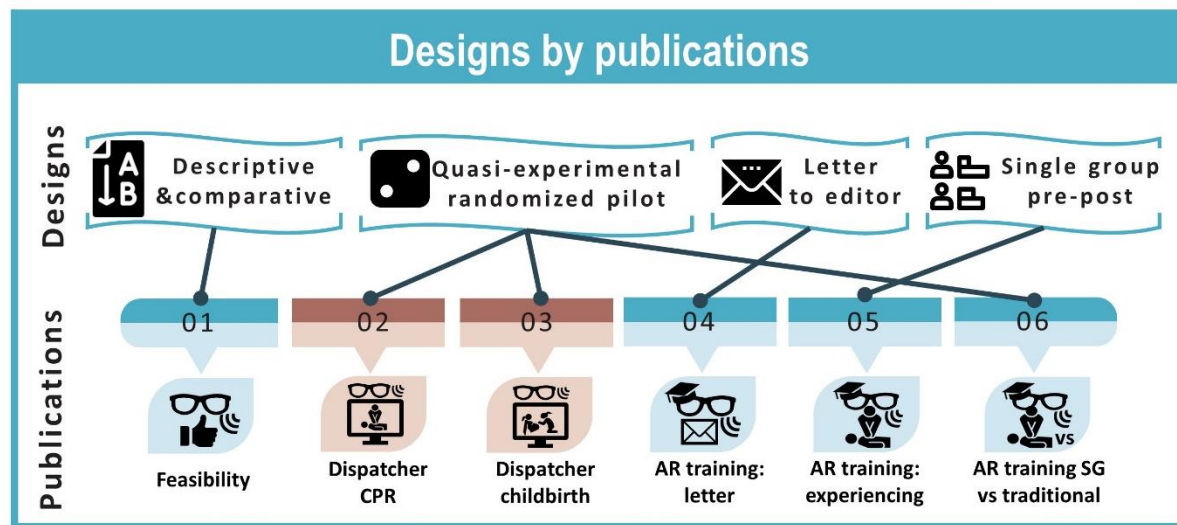


Figure 5-1. Designs of each study
(Author-created figure)

5.2 PARTICIPANTS AND ETHICS

All the studies were in accordance with the principles of the Declaration of Helsinki and were approved by the Ethics Committee for Clinical Research of the Catalan Sports Council (Appendix 1). Signed informed consent was obtained from all participants prior to the study.

5.3 SMART GLASSES: CONNECTIVITY AND FAMILIARIZATION

Before the intervention, each participant became familiar with the basic functions of the smart glasses in their use of video calls in a short training < 5 minutes.

The smart glasses (Vuzix Blade Upgraded, Vuzix, US) were connected via a 4G wireless network. The smart glasses had the Vuzix Remote Assist App (VRA App) installed, which allows making video calls with another device (Figure 5-2). In our studies it was with a laptop

connected to the web page of the application (<https://vra.vuzix.com>) handled by dispatcher or instructor.



Figure 5-2. Smart glasses characteristics.
(Author-created figure)

5.4 CLINICAL SIMULATION, INSTRUMENTAL, AND VARIABLES

All studies were conducted in a simulation scenario where the participant performed in an out-of-hospital emergency or trained. In the studies on video assistance, it was sought that the simulation scenarios were located in the most realistic location possible: Article 01 sailing in a boat, Article 02 in a college building in an urban environment, and Article 03 on the sand of a beach. Studies on basic life support training (Article 05 and 06) were done in a university classroom.

Each participant underwent basic life support performance/training in an out-of-hospital cardiorespiratory arrest scenario, with the exception of Article 03, which was an unplanned out-of-hospital childbirth.

The simulations of the out-of-hospital cardiorespiratory arrest were performed using a resuscitation manikin (Little Anne QCPR manikin or Resusci Anne QCPR, Laerdal, Norway) connected to APP CPR instructor or a SimPad PLUS (Laerdal, Norway), and an AED Trainer (AED Trainer 2, Laerdal, Norway). In general, we analyzed sociodemographic variables, items in the BLS protocol (assessed dichotomously as performed correctly or incorrectly, according to the European Resuscitation Council guidelines[4]), chest compression quality, performance times, self-perceptions of performance and confidence for delivering CPR in real-life situations (rated on scale of 0–10, where 10 indicated excellent) and perceived ease of use of the smart glasses (0–10, where 10 indicated very difficult) (Figure 5-3).

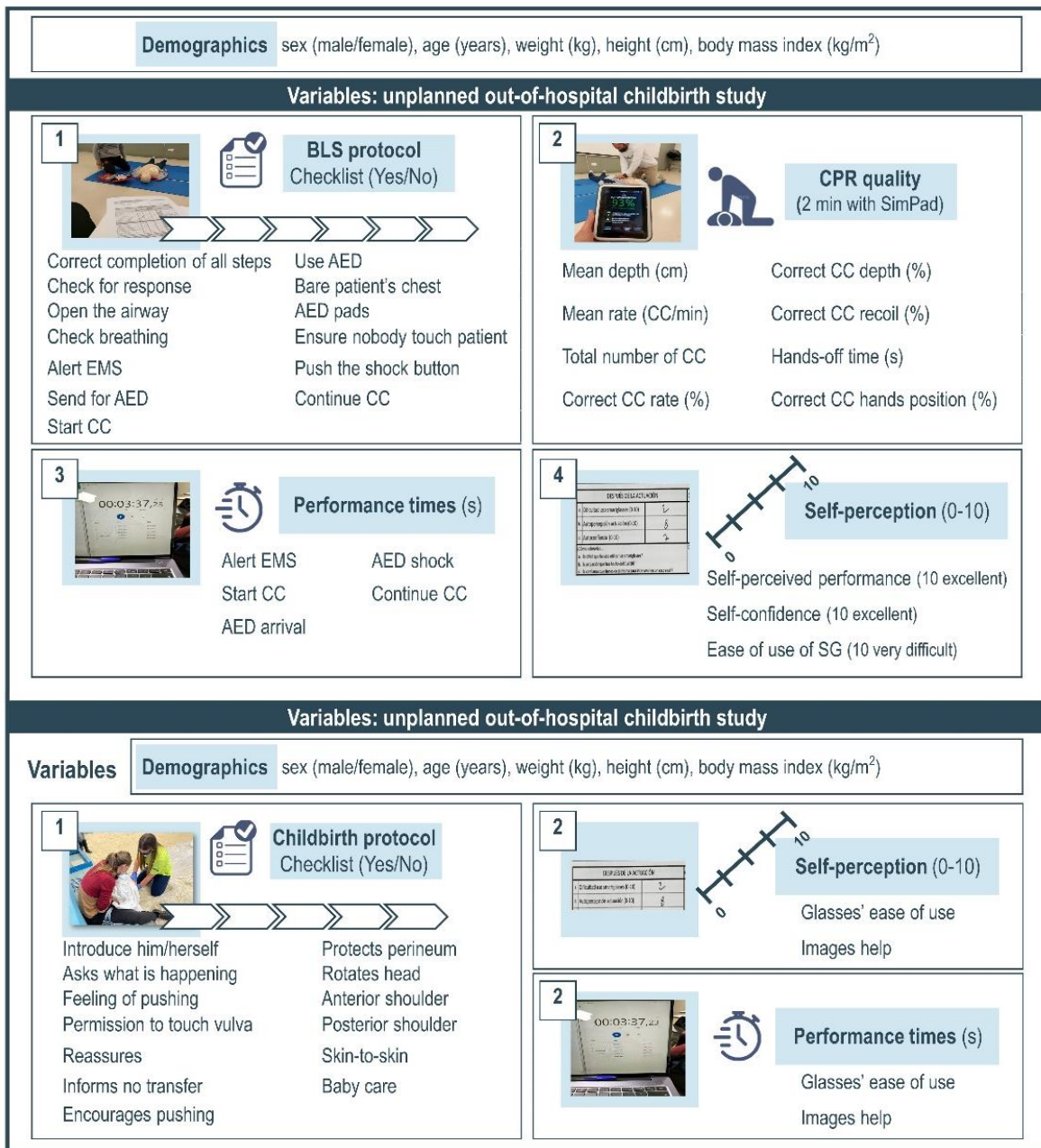
The simulations of the unplanned out-of-hospital childbirth were performed using a midwife handled a maternal–fetal simulator (PROMPT Flex, Laerdal, Norway) and the following variables were analyzed: eutocic birth performance protocol measured dichotomously (performed/not performed, according to the clinical practice guideline for out-of-hospital childbirth[40]) and categorizing the variables into technical or non-technical skills, total action time, subjective perception variables were measured on a scale of 0–10 (ease of use of the smart glasses, with 10 being very difficult), and opinion on whether the photos projected on the smart glasses facilitated the performance (with 10 being very high) (Figure 5-3).

5.5 PROCEDURE

In general, in dispatcher assistance studies (Articles 01, 02, 03), a group of participants was asked to perform with the help of the emergency expert by communicating via video call with smart glasses and compared with the control condition (no assistance or traditional phone assistance). Otherwise, in training studies (Articles 05, 06), the quality of the performance in the event of out-of-hospital cardiorespiratory arrest was recorded after having learned with video assistance with smart glasses in communication with a telematic trainer. And it was compared with the baseline or with the control group of face-to-face traditional teaching methodology. Details of the procedure for each study can be found in the Articles themselves.

5.6 DATA ANALYSIS

Statistical analyses were performed in IBM SPSS Statistics software (v.20.Windows, Armonk, NY: IBM Corp). Categorical variables were described through absolute and relative frequencies, and continuous variables were described through measures of central tendency (mean or median), dispersion (standard deviation or interquartile range [IQR]). Between-group comparisons were performed using the t-test (or the Rank test for non-normally distributed variables). Qualitative variables from the BLS protocol were compared using the Chisquare test. Effect sizes were measured for quantitative variables with significant differences using the Cohen's d test (or the Rosenthal's r test for non-normally distributed variables). They were classified as trivial (<0.2) small (0.2–0.5), moderate (0.5–0.8), large (0.8–1.3), or very large (≥ 1.3). The Cramer V test was used to calculate the effect sizes for qualitative variables, classified as small (0.1–0.3), medium (0.3–0.5), or large (≥ 0.5). Significance was set at $p < 0.05$.



6. RESULTS

6 RESULTS

6.1 FEASIBILITY OF COMMUNICATION WITH SMART GLASSES IN OUT-OF-HOSPITAL SETTING

6.1.1 Article 01 - Title: Are smart glasses feasible for dispatch prehospital assistance during on-boat cardiac arrest? A pilot simulation study with fishermen.

Internal and Emergency Medicine
<https://doi.org/10.1007/s11739-023-03251-6>

EM - ORIGINAL



Are smart glasses feasible for dispatch prehospital assistance during on-boat cardiac arrest? A pilot simulation study with fishermen

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Figure 6-1. Screenshot of article 01 identification.
 Available at <https://link.springer.com/article/10.1007/s11739-023-03251-6>

6.1.1.1 Article abstract

The aim of the study was to explore feasibility of basic life support (BLS) guided through smart glasses (SGs) when assisting fishermen bystanders. Twelve participants assisted a

simulated out-of-hospital cardiac arrest on a fishing boat assisted by the dispatcher through the SGs. The SGs were connected to make video calls. Feasibility was assessed whether or not they needed help from the dispatcher. BLS-AED steps, time to first shock/compression, and CPR's quality (hands-only) during 2 consecutive minutes (1st minute without dispatcher feedback, 2nd with dispatcher feedback) were analyzed. Reliability was analyzed by comparing the assessment of variables performed by the dispatcher through SGs with those registered by an on-scene instructor. Assistance through SGs was needed in 72% of the BLS steps, which enabled all participants to perform the ABC approach and use AED correctly. Feasibility was proven that dispatcher's feedback through SGs helped to improve bystanders' performance, as after dispatcher gave feedback via SGs, only 3% of skills were incorrect. Comparison of on-scene instructor vs. SGs assessment by dispatcher differ in 8% of the analyzed skills: greatest difference in the "incorrect hand position during CPR" (on-scene: 33% vs. dispatcher: 0%). When comparing the 1st minute with 2nd minute, there were only significant differences in the percentage of compressions with correct depth (1st: $48 \pm 42\%$, 2nd: 70 ± 31 , $p = 0.02$). Using SGs in aquatic settings is feasible and improves BLS. CPR quality markers were similar with and without SG. These devices have great potential for communication between dispatchers and laypersons but need more development to be used in real emergencies.

6.1.1.2 Evidence of Quality

This article was published in *Internal and Emergency Medicine* (ISSN: 1828-0447, Publisher: Springer). It is cataloged in the Web of Science and Scopus repositories in the field of *Internal and Emergency Medicine*, and *Emergency Medicine*, respectively.

Impact factor and quartiles:

| Indexing database | Impact Factor | Quartile | Category |
|-------------------------------|---------------|----------|---------------------------------|
| Journal Citation Report (JCR) | 4.6 | Q2 | Internal and Emergency Medicine |
| SCImago Journal Rank (SJR) | 0.93 | Q1 | Emergency Medicine |

Since its publication (April 24, 2023) up to the present moment (November 16, 2023), the citations obtained by this article have been as follows:

| Indexing database | Number of cites |
|---------------------------|-----------------|
| WoS Core Collection (JCR) | 1 |
| Scopus | 2 |
| Google Scholar | 2 |

Full citation of the manuscript:

Roberto Barcala-Furelos, **Silvia Aranda-García***, Martín Otero-Agra, Felipe Fernández-Méndez, Alejandra Alonso-Calvete, Santiago Martínez-Isasi, Robert Greif, Antonio Rodríguez-Núñez. **Are smart glasses feasible for dispatch prehospital assistance during on-boat cardiac arrest? A pilot simulation study with fishermen.** Intern Emerg Med. 2023 Apr 4; <https://doi.org/10.1007/s11739-023-03251-6>

Specific contribution of the PhD candidate to the article:

Conception and design of the study, methodology, investigation, data curation; drafting of the manuscript and revision after peer-review, visualization, and (*) corresponding author.

Full text:



Are smart glasses feasible for dispatch prehospital assistance during on-boat cardiac arrest? A pilot simulation study with fishermen

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Abstract

The aim of the study was to explore feasibility of basic life support (BLS) guided through smart glasses (SGs) when assisting fishermen bystanders. Twelve participants assisted a simulated out-of-hospital cardiac arrest on a fishing boat assisted by the dispatcher through the SGs. The SGs were connected to make video calls. Feasibility was assessed whether or not they needed help from the dispatcher. BLS-AED steps, time to first shock/compression, and CPR's quality (hands-only) during 2 consecutive minutes (1st minute without dispatcher feedback, 2nd with dispatcher feedback) were analyzed. Reliability was analyzed by comparing the assessment of variables performed by the dispatcher through SGs with those registered by an on-scene instructor. Assistance through SGs was needed in 72% of the BLS steps, which enabled all participants to perform the ABC approach and use AED correctly. Feasibility was proven that dispatcher's feedback through SGs helped to improve bystanders' performance, as after dispatcher gave feedback via SGs, only 3% of skills were incorrect. Comparison of on-scene instructor vs. SGs assessment by dispatcher differ in 8% of the analyzed skills: greatest difference in the "incorrect hand position during CPR" (on-scene: 33% vs. dispatcher: 0%). When comparing the 1st minute with 2nd minute, there were only significant differences in the percentage of compressions with correct depth (1st: $48 \pm 42\%$, 2nd: 70 ± 31 , $p = 0.02$). Using SGs in aquatic settings is feasible and improves BLS. CPR quality markers were similar with and without SG. These devices have great potential for communication between dispatchers and laypersons but need more development to be used in real emergencies.

Keywords Smart glasses · Video dispatch · Out-of-hospital cardiac arrest · Bystander · Cardiopulmonary resuscitation

Abbreviations

| | | | |
|-----|-----------------------------------|------|--------------------------------|
| AED | Automated external defibrillator | CPR | Cardiopulmonary resuscitation |
| ABC | Airway, breathing and circulation | ERC | European resuscitation council |
| BLS | Basic life support | EMS | Emergency medical services |
| CC | Chest compressions | OHCA | Out-of-hospital cardiac arrest |
| | | SGs | Smart glasses |

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Introduction

The 2021 European Resuscitation Council (ERC) Guidelines suggest that emergency medical services (EMS) should consider the use of technology such as video communication to communicate with bystanders and provide dispatcher-assisted cardiopulmonary resuscitation (CPR) [1]. Smartphones are currently the most frequently used devices for video calls. However, the future of video communication could be the head-worn devices (HWD), which are portable, hands-free gadgets with a small optic in front of the eyes. These innovative devices can help in different areas related to physical and cognitive workload or in task complexity [2]. Smart glasses (SGs) are considered a HWD and allow communication between a receiver (dispatcher) and the user in real time. This communication can favor that there is better performance in emergencies in which the bystander needs the help of the dispatcher [3]. The performance of SGs has increased in terms of a longer battery life, less weight, greater comfort, enhanced hardware and software improvements with new cutting-edge communication apps [2].

In the out-of-hospital emergency field, a potential application which does not yet have usability analysis is the video-streaming dispatch with SGs used by bystanders in remote areas like the ocean coast. Out-of-hospital cardiac arrest (OHCA) in peculiar settings such as water areas is described in the ERC guidelines as a special resuscitation situation [4].

The target population for this study were fishermen who have worked in high-risk situations for many years. Fishing is a high-risk profession in which one-fifth of fishermen had been involved in a medical emergency at sea that required them to be evacuated to shore for immediate treatment [5]. 1.3% of very serious accidents during fishing are heart attacks, and an additional 38.7% are situations that can cause cardiorespiratory arrests such as drowning or hypothermia [6]. They are usually located far away from specialized medical help, with an extremely limited number of witnesses nearby [7]. This means that medical emergencies in aquatic settings are, inevitably potentially recurring situations, bearing in mind such an uncontrolled and remote environment.

Under these conditions, the hypothesis of this feasibility study was that basic life support (BLS) guided by an emergency dispatcher through SGs would improve and assist bystander's decision making and the performance of correct BLS steps as primary outcome. Furthermore, secondary outcomes were the reliability and accuracy of the emergency dispatcher's assessment, which would be comparable to an on-scene dispatcher (the gold standard), and CPR-quality markers. Therefore, the aim of this pilot simulation study was to analyze the sequence of the ABC approach, the

automated external defibrillator (AED) use, and the correct steps of the CPR skills performed by fishermen who are assisted using the SGs innovative tool.

Methods

Design

A descriptive and comparative design was used to test the feasibility and reliability of SGs during video assistance in a simulated OHCA undertaken by fishermen sailing in a small fishing boat.

Participants

A total of 16 coastal fishermen were invited to participate in this study. The inclusion criteria were to be professional fishermen with at least 10 years of experience (to ensure fully familiar with the boat and with performing tasks while sailing) who had not undergone BLS training in the previous 6 months. Finally, 12 fishermen (100% male) were included. Four were excluded because they had received BLS training within the last 6 months. The mean age of participants was 46 ± 4 years (95% confidence interval [CI] 43–48) (Fig. 1). Before starting the study, informed consent was requested from all participants. The study was approved by the Ethics Committee for Clinical Research of the Catalan Sports Council (022/CEICGC/2021).

Very brief training on smart glasses and connection details

The first phase of the pilot study consisted of the fishermen's familiarization with the use of SGs. The training was conducted on board of a boat that was moored in the harbor with the engine turned off. Each participant put on the SGs for 5 min and had a brief conversation with the emergency dispatcher who was located at a facility near the harbor. The connection to the SGs (Vuzix Blade AR, United States) was made via a 4G wireless network, previously configured using the VRA Mobile App (Vuzix, United States). The SG's characteristics can be seen in Fig. 2.

Trial environment

The connection was established by navigating at 10kn at half a nautical mile from land. The fishing boat was 6 m long and its beam measured 3 m. The crew consisted of a skipper at the helm, a fisherman (the bystander), and two people from the research team (a communication technician and a BLS instructor). Data collection was performed on August 20, 2021, between 16:00 and 20:00 in the port of

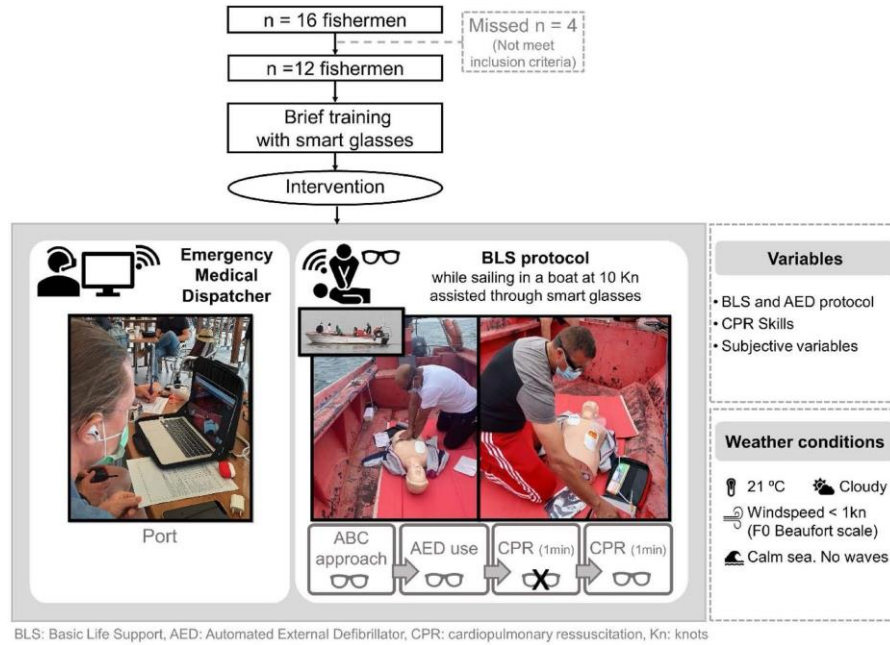


Fig. 1 Flow chart outlining the design and procedures

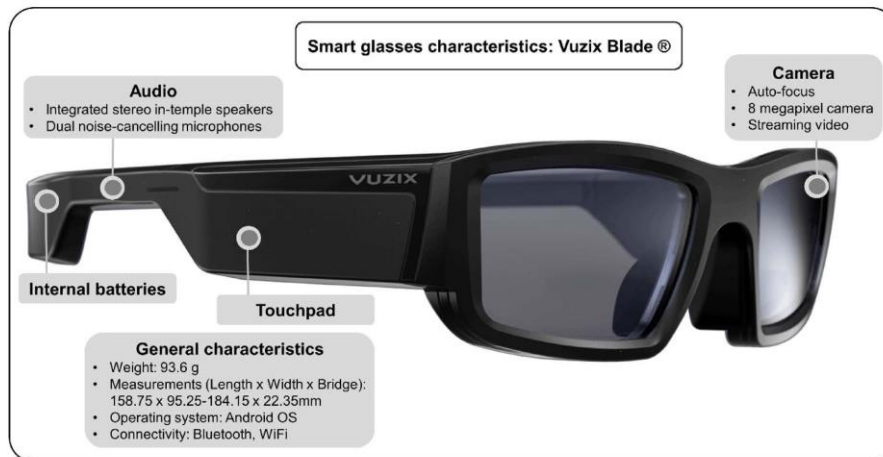


Fig. 2 Smart glasses characteristics

Rianxo (Spain), located on the Atlantic coast at GPS position: 42°38'49"–8°49'30". The weather conditions were: 21 °C, cloudy, with a wind speed < 1 kt (F0 on the Beaufort scale), in a calm sea with no waves.

Clinical simulation and variables

Step 1 Cardiac arrest on boat.

The on-boat instructor presented the following clinical simulation individually to each participant:

"A fisherman from the crew collapses on the boat while performing some physical exertion. The victim is on the ground and is simulated by a manikin. The boat is also equipped with an AED. You have the SGs on and they are connected to a control center" (see supplemental video).

Step 2 ABC approach and AED response.

The bystander had to initiate victim assistance when the boat was cruising at 10kn and when instructed to do so by the researcher.

Analysis variables consisted of the following BLS steps: 1. check response, 2. open victim's airway, 3. check breathing, 4. bring in an AED, 5. place the AED pads properly, 6. deliver a shock, 7. perform chest compressions (CC) after AED shock, and 8. correct hand placement during CC. Feasibility was assessed dichotomously as YES (i.e., skill performed correctly by the witness without the need to dispatch) or NO (i.e., omission of the step or performed incorrectly/not effectively). Dispatcher assistance was provided through SGs if the fisherman did NOT perform the step, did not perform the step in the correct order or performed it incorrectly. Time (in seconds) from the start of the procedure to the first shock and the first cardiac compression was analyzed quantitatively.

Reliability was analyzed by comparing the assessment of each variable performed by the dispatcher through the SGs with an on-scene instructor in the boat, who recorded the same eight variables. The instructor did not interact with the participants at any time.

Step 3 CPR skills with SGs dispatch.

After step 2, the bystanders initiated hands-only CPR for 2 min. During the 1st minute, they received no communication from the dispatcher and during the 2nd minute, they received continuous feedback from the dispatcher; min 1 (no dispatcher feedback) vs. min 2 (with dispatcher feedback).

The evaluated CPR-quality markers were: (a) CC with a correct rate as a percentage (CC-RA %), (b) CC with correct depth as a percentage (CC-D %), (c) CC with full chest release as a percentage (CC-RE %), and (d) CC with correct hand position as a percentage (CC-HP %). The reference values were those indicated for CC by the ERC guidelines in 2021 [1]; at a rate of 100–120 cc/min and depth of 50–60 mm with full chest recoil and hand placement in the middle of the chest. Skill recording was obtained using

the APP CPR instructor (Laerdal, Norway), which was connected to the Little Anne QCPR manikin (Laerdal, Norway).

Data analysis

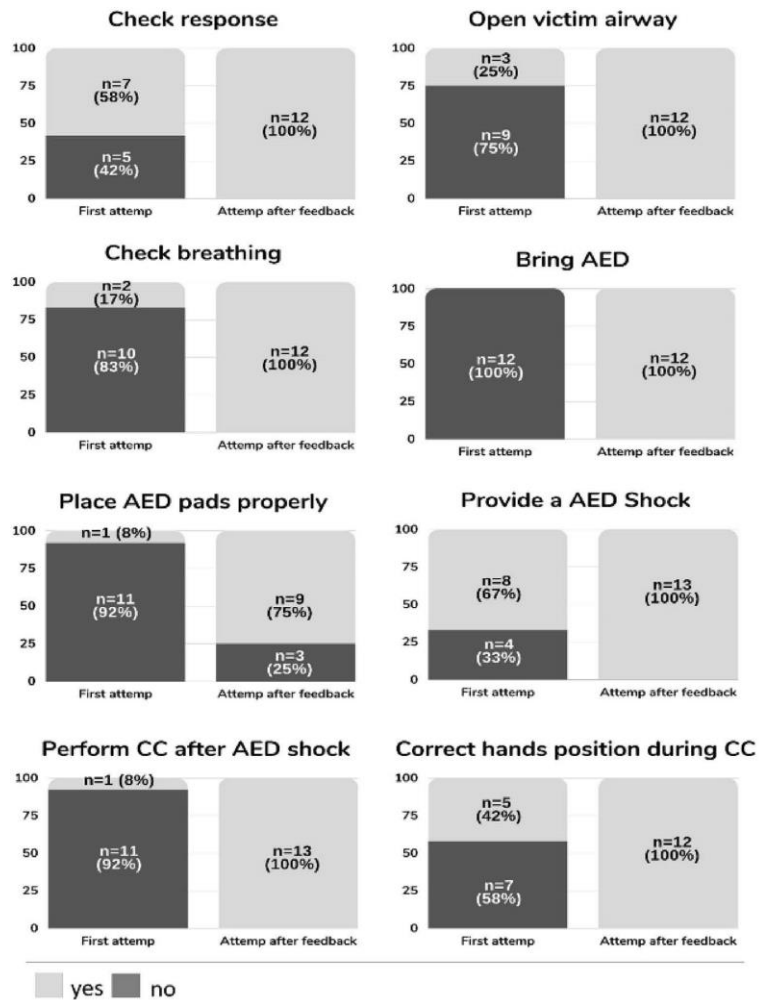
Statistical analysis was performed with IBM SPSS Statistics for Windows software, version 20.0 (Armonk, NY: IBM Corp). Categorical variables were described through absolute and relative frequencies. Continuous variables were described through measures of central tendency (mean), dispersion (standard deviation) and confidence estimators (95% confidence intervals). Means comparisons were performed using Student's *t* test for variables that met the criteria of normality and the Wilcoxon rank sum test was used for variables that did not meet the criteria of normality. For comparisons that presented statistically significant differences, the effect size was calculated using the Rosenthal test and had the following classification: trivial (< 0.2); small (0.2–0.5); moderate (0.5–0.8); large (0.8–1.3); very large (> 1.3).

Results

All 12 fishermen were able to complete the study by performing the ABC approach and using AED sequentially and correctly, but this was always achieved with the help of the dispatcher's feedback through the SGs. The result analysis disaggregates: (a) the steps of the BLS protocol that the lay person (fisherman) omitted or performed incorrectly and what should have been indicated or corrected by the dispatcher through the SGs, (b) the reliability analysis of the SGs comparing the dispatcher's final evaluation with that of an on-scene instructor, (c) CRP-quality markers, and (d) time to first defibrillation and time to initiation of CC.

- (a) Feasibility results: the dispatcher had to give feedback to all participants (100%). Out of a total of 96 skills that were assessed, assistance was given in 65 of the steps, which represented 72% of the interventions. The skills that received the most instructions were those related to the AED use. After dispatch through the SGs, only 3% of skills were not completed at the dispatcher's discretion (Fig. 3).
- (b) Reliability results: comparison of the on-scene instructor's assessment vs. the SGs assessment by dispatcher differed in 8% of the skills analyzed. The largest difference was found in the variable "correct hand position during CC", which the dispatcher considered correct in 100% of the participants, while the on-scene instructor indicated that 33% were neither placing their hands in the center of the chest nor in accordance with the recommendations for resuscitation (Fig. 4).

Fig. 3 Percentage of correct steps in ABC approach before and after dispatcher assistance through smart glasses



(c) CPR-quality markers: the mean depth of compressions during the 2 min of resuscitation was 54 ± 11 mm (95% CI 47–61). We only found a significant difference in the variable CC depth (1st minute: $48 \pm 42\%$, 2nd minute: $70 \pm 31\%$, $p=0.02$, $EN=0.48$) (Table 1) comparing the 1st minute (without feedback dispatcher) and the 2nd minute (with dispatcher feedback through SGs). This represents 22% in favor of the 2nd minute with telecare using the SGs. The rest of the CPR variables remained unchanged between 1st and 2nd minutes.

(d) The time from the start of the intervention to defibrillation was 162 ± 26 s, and 14 ± 6 s from defibrillation to the start of CPR.

Discussion

The aim of this study was to evaluate the feasibility of SGs as a means of support between an emergency dispatcher and a bystander during BLS in a special resuscitation setting, such as a small fishing boat during sea transport.

Fig. 4 On-scene instructor vs. dispatcher evaluation comparison through smart glasses

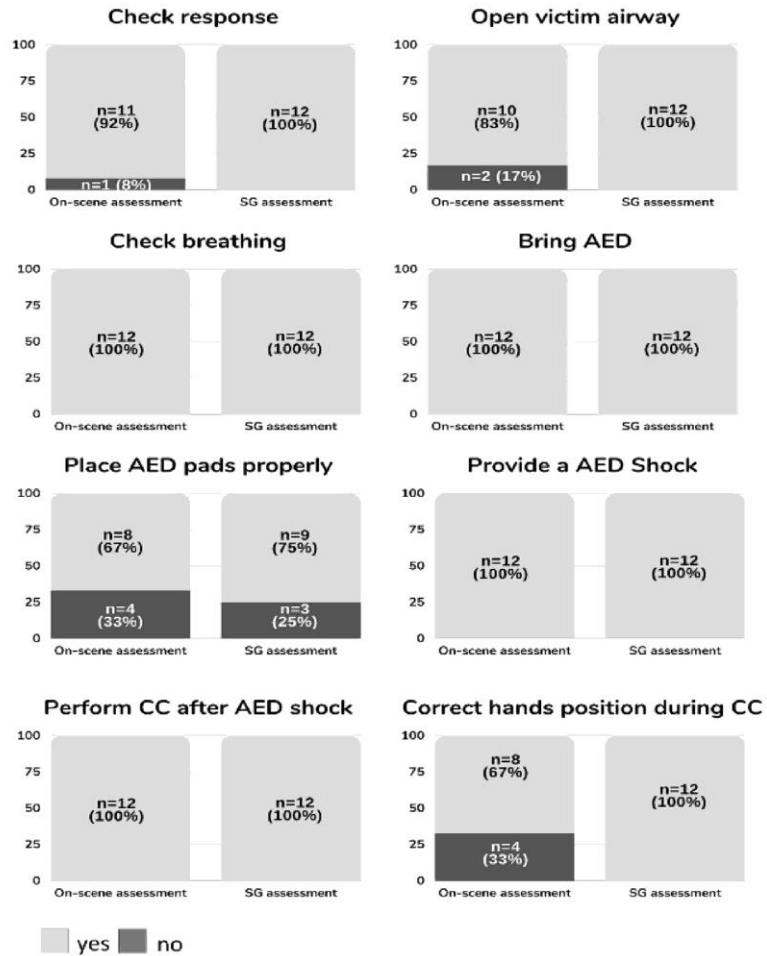


Table 1 Results of CPR skills by minute

| | Without assistance with SGs (1st minute) | | Video-assisted with SGs (2nd minute) | | p value [effect size] |
|-----------|--|-----------------|--------------------------------------|-----------------|---------------------------------|
| | Mean ± SD | CI ^b | Mean ± SD | CI ^b | |
| CC-RA | 96 ± 21 | 83–110 | 98 ± 13 | 89–106 | p = 0.67 |
| CC-D (%) | 48 ± 42 | 21–74 | 70 ± 31 | 50–90 | p = 0.02 [ES 0.48] ^a |
| CC-RE (%) | 33 ± 40 | 8–58 | 41 ± 34 | 19–63 | p = 0.21 |
| CC-HP (%) | 53 ± 49 | 22–84 | 54 ± 49 | 23–85 | p = 0.89 |

CI confidence interval, CPR cardiopulmonary resuscitation, SD standard deviation, SGs smart glasses, CC-RA chest compression (CC) rate, CC-D CC depth (50–60 mm) in percentage, CC-RE CC with full chest recoil in percentage, CC-HP CC with correct hands placement in percentage

^aSmall effect size with Rosenthal test

^b95% CI

The main findings were: (a) The use of SGs was feasible in all tests and helped the bystanders to correctly follow all BLS steps in a cardiac-arrest-simulated scenario; (b) SGs were especially useful during the ABC approach and the AED response, but to a lesser extent in CPR-quality markers; (c) the final evaluation of the items corrected by the dispatcher had a high agreement with the assessment of the items by the on-scene instructor, suggesting a high level of reliability.

Witnesses have a fundamental role in the treatment of OHCA [8] but they do not always take the initiative, often failing to recognize cardiac arrest or simply feeling unable to act [9]. However, with the development of telecommunications [10], the identification and response to OHCA have improved with the emergence of the emergency dispatcher [11, 12]. The evolution of 4G and 5G wireless systems [9] is leading to a transition from telephone dispatchers to a new form of dispatcher based on real-time video streaming [11, 13], although there is still a lack of evidence in this regard [10]. Scientific literature has identified limitations related to the number of witnesses required for the video call (at least two) [11, 13], the difficulty of communication between the dispatcher and the bystander [14, 15] or even the position of the camera [16]. A large number of these limitations may be due to the type of device most common in this type of communication: the smartphone [9–11, 15, 17]. However, SGs can circumvent these limitations, as they connect the responder with the dispatcher first, without the need for additional witnesses. In addition, they enable hands-free use and the camera position is right above the victim.

One of the key strengths of livestreaming is that the dispatcher can see what is happening and make decisions about it. In a studio in Copenhagen called Good Sam, a telephone dispatcher was offered first and then a video call dispatcher if there were two witnesses. The live transmission was successful in 82% of the calls and the condition of the patients changed in 51%, resulting in a change in the emergency of 27.5% after receiving the video support [11]. In this study, communication could be established in all tests and the dispatcher was able to guide or correct the bystander's maneuvers in 72% of the ABC stages and improve CC depth.

The most relevant and pertinent aspects in cardiac arrest is early defibrillation and early CPR [1, 17]. The fishermen in this study took 2.5 min to deliver the first shock and 14 s longer to initiate CPR. Although the aim is to do this as soon as possible, they would probably take longer or fail without the help of the dispatcher, who could see that no fisherman approached the AED on their own (without the help of the dispatcher through the SG) and that on numerous occasions, the fishermen did not place the AED patches correctly. In real life, defibrillation delays of 2 min or more are not uncommon even with medical staff and AED in situ,

as was observed in the cardiac arrest during the broadcast of the Euro 2021 international soccer competition [18].

The study by Bolle et al. with young video-guided students showed that it took approximately 1.5 min from the start of the test to the first compression [15], but it should be noted that this was a controlled environment, very different from that of fishermen sailing during their intervention.

Emergency dispatchers are trained to provide CPR instructions following a predefined protocol [19]. Ecker et al. found improved performance when bystanders performed CPR with video assistance vs. only with call assistance. Significant differences in the depth of compression were observed but especially in the placement of hands in the correct compression site [9].

However, there were no major differences in the comparison with audio dispatcher assistance. In this study, the comparison of the 1st minute without dispatcher feedback vs. the 2nd minute, the emergency dispatcher provided ongoing feedback through the SGs. A significant improvement in the CC depth was achieved with 70% quality in CC-D, but not so in CC-HP which barely surpassed 50% in quality.

Then how was it possible that the bystanders' depth results improved with SGs, while there was no modification in the position of the hands? In the authors' opinion, the zenithal view can provide a depth perspective since the sinking of the chest is noticeable, but the contact surface of the CC cannot be visualized. The dispatcher cannot tell whether the bystander is supporting the whole hand or just the heel. In addition, the CC reference is lost several times because during CPR, the anatomical position with the head projected beyond the arms causes the camera view to be lost in this maneuver.

This circumstance could be corrected by modifying the protocols of the dispatcher for handling video calls [15] and with technical adaptations such as a wide-angle lens. The study of the camera position is a relevant issue and the study by Wetsch et al. with smartphones placed on a tripod suggests that the best location is the side position, since it offers better error detection, but only for the CPR and not for the BLS sequence [16]. A novelty of this study is the zenith and dynamic position of the camera in the SGs, with the bystander's hands free, which allowed the dispatcher to perform a good evaluation of the ABC approach albeit with errors in the HP. This error caused by the device could be seen in the reliability analysis through the on-scene instructor analysis. In all other steps, there was almost complete agreement between the two evaluations.

Implications for practice

This study has served to test a commercial model of SGs with features common to most of the devices available on the market, but not specifically designed to guide BLS. The

major strength is the possibility for a single hands-free witness to have quality two-way communication in a challenging setting such as an aquatic environment, which is a non-controllable scenario.

Another strength is the bone conduction hearing mechanism, which makes it easy to receive the dispatcher's indications even in spite of wind or engine noise. SGs are currently an affordable product and their price is similar to that of high-end smartphones. On the other hand, they also have important limitations, such as camera angle range or switch on. In our study, the device was switched on, but the start-up time is approximately 40 s. Another limiting aspect is bystanders with optical problem (such as myopia) as he or she would have difficulty viewing the display projected on the optics. During testing, heating of the device was noticed which should be addressed by the manufacturers. Prolonged use could cause discomfort for the rescuer or failures in the device itself (i.e., automatic switch off). To improve the procedure, the dispatcher could ask the bystander, wearing the SG, to look at the position of his/her own hands during the first CCs.

Limitations of this study

This study was proposed as a pilot feasibility study to test the usability of the glasses in a special setting with fishermen. For this reason, the sample size was small. Therefore, the study was not powered to investigate possible differences in CPR-quality markers. The results may differ with larger samples, in other settings, and with other conditions. Connectivity at the study location was advanced and in other regions that might be a major limitation. This was a simulation study, so applicability in real situations should be carefully evaluated before implementation.

Conclusion

The use of SGs in aquatic settings seems feasible if the right wireless connectivity conditions are available. Communication between the emergency dispatcher and the witness is seamless and is especially helpful during the dispatch of the ABC approach and AED use. The small sample size did not allow to investigate significant differences in CPR-quality markers. We consider that these devices have great potential for communication between dispatchers and laypersons but need improvement to be used in real emergencies.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s11739-023-03251-6>.

Author contributions RBF: conceptualization; methodology; formal analysis; investigation; resources; writing—original draft; visualization; supervision. SAG: conceptualization; methodology; investigation;

data curation; writing—original draft; visualization. MOA: investigation; data curation; software; formal analysis. ffm: methodology; investigation; software; writing—review and editing. AAC: investigation; resources; writing—review and editing. SMI: investigation; software; writing—review and editing. RG: investigation; writing—review and editing. ARN: conceptualization; methodology; investigation; resources; writing—review and editing; supervision.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare they have no conflict of interest to declare regarding this article.

Compliance with Ethical Standards This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee for Clinical Research of the Catalan Sports Council (022/CEICGC/2021). Before starting the study, informed consent was requested from all participants.

Informed consent The informed consent included information on both their rights as participants in the study (voluntary participation in the study, data processing respecting anonymity...), as well as the assignment of rights to images for academic or scientific outreach purposes.

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Supplementary materials:

The following supplementary video can be downloaded at:
<https://x.com/silviaaranda46/status/1646514717341667329?s=20>



6.2 TELEASSISTANCE WITH AUGMENTED REALITY THROUGH SMART GLASSES FOR RESPONDING TO OUT-OF-HOSPITAL EMERGENCIES

Article 02 - Title: Dispatcher-assisted basic life support for lay bystanders: A pilot study comparing video streaming via smart glasses and telephone instructions.

Article 03 - Title: “Dispatcher, Can You Help Me? A Woman Is Giving Birth”. A Pilot Study of Remote Video Assistance with Smart Glasses.

6.2.1 Article 02 - Title: Dispatcher-assisted basic life support for lay bystanders: A pilot study comparing video streaming via smart glasses and telephone instructions.

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Dispatcher-assisted BLS for lay bystanders: A pilot study comparing video streaming via smart glasses and telephone instructions



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Figure 6-2. Screenshot of article 02 identification.

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6.2.1.1 Article abstract

Objective: To determine whether dispatcher assistance via smart glasses improves bystander basic life support (BLS) performance compared with standard telephone assistance in a simulated out-of-hospital cardiac arrest (OHCA) scenario. **Methods:** Pilot study in which 28 lay people randomly assigned to a smart glasses-video assistance (SG-VA) intervention group or a smartphone-audio assistance (SP-AA) control group received dispatcher guidance from a dispatcher to provide BLS in an OHCA simulation. SG-VA rescuers received assistance via a video call with smart glasses (Vuzix, Blade) connected to a wireless network, while SP-AA rescuers received instructions over a smartphone with the speaker function activated. BLS protocol steps, quality of chest compressions, and performance times were compared. **Results:** Nine of the 14 SG-VA rescuers correctly completed the BLS protocol compared with none of the SP-AA rescuers ($p = 0.01$). A significantly higher number of SG-VA rescuers successfully opened the airway (13 vs. 5, $p = 0.002$), checked breathing (13 vs. 8, $p = 0.03$), correctly positioned the automatic external defibrillator pads (14 vs. 6, $p = 0.001$), and warned bystanders to stay clear before delivering the shock (12 vs. 0, $p < 0.001$). No significant differences were

observed for performance times or chest compression quality. The mean compression rate was 104 compressions per minute in the SG-VA group and 98 compressions per minute in the SP-AA group ($p = 0.46$); mean depth of compression was 4.5 cm and 4.4 cm ($p = 0.49$), respectively. Conclusions: Smart glasses could significantly improve dispatcher-assisted bystander performance in an OHCA event. Their potential in real-life situations should be evaluated.

6.2.1.2 Evidence of Quality

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ABSTRACT

Objective: To determine whether dispatcher assistance via smart glasses improves bystander basic life support (BLS) performance compared with standard telephone assistance in a simulated out-of-hospital cardiac arrest (OHCA) scenario.

Methods: Pilot study in which 28 lay people randomly assigned to a smart glasses-video assistance (SG-VA) intervention group or a smartphone-audio assistance (SP-AA) control group received dispatcher guidance from a dispatcher to provide BLS in an OHCA simulation. SG-VA rescuers received assistance via a video call with smart glasses (Vuzix, Blade) connected to a wireless network, while SP-AA rescuers received instructions over a smartphone with the speaker function activated. BLS protocol steps, quality of chest compressions, and performance times were compared.

Results: Nine of the 14 SG-VA rescuers correctly completed the BLS protocol compared with none of the SP-AA rescuers ($p = 0.01$). A significantly higher number of SG-VA rescuers successfully opened the airway (13 vs. 5, $p = 0.002$), checked breathing (13 vs. 8, $p = 0.03$), correctly positioned the automatic external defibrillator pads (14 vs. 6, $p = 0.001$), and warned bystanders to stay clear before delivering the shock (12 vs. 0, $p < 0.001$). No significant differences were observed for performance times or chest compression quality. The mean compression rate was 104 compressions per minute in the SG-VA group and 98 compressions per minute in the SP-AA group ($p = 0.46$); mean depth of compression was 4.5 cm and 4.4 cm ($p = 0.49$), respectively.

Conclusions: Smart glasses could significantly improve dispatcher-assisted bystander performance in an OHCA event. Their potential in real-life situations should be evaluated.

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1. Introduction

Bystander action is critical to patient survival following an out-of-hospital cardiac arrest (OHCA) [1–3]. Unfortunately, those in a position to help do not always have the knowledge, skills, or mindset to perform basic life support (BLS), with up to 65% of patients who experience OHCA receiving no assistance until the ambulance arrives [1,4].

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The European Resuscitation Council (ERC) guidelines highlight the importance of promoting community-implemented CPR by equipping telephone dispatchers with the necessary skills to provide guidance on bystander CPR and high-quality chest compressions [2]. Telephone guidance to lay rescuers, however, is challenging, as the communication is verbal only. This has been proposed as one of the reasons why dispatcher-assisted CPR has not been as successful as expected [5,6]. Dispatchers have difficulty determining whether the patient is breathing normally in approximately 30% of OHCA cases [7], whether because the rescuer provides contradictory information or because they say that they cannot or do not know how to assess breathing [8].

Video assistance has been linked to improved survival and neurological outcomes in real-life situations [9]. The reasons are simple: the dispatcher is able to see what is happening and where and what is being done. The benefits of video, however, have also been called into question, as it can result in delays in the initiation of CPR [10]. Wearable technology such as smart glasses with video streaming functionality could overcome the above challenges and improve the delivery of dispatcher-assisted BLS. The use of smart glasses in out-of-hospital environments has been limited to assistance with disaster triage [11], an unplanned birth [12], and, with promising results, resuscitation following cardiac arrest on a small boat [13]. Smart glasses are still a relatively new communication technology, but as occurred with smartphones, widespread adoption is probably not far off. The American Heart Association Guidelines for Cardiopulmonary Resuscitation recommended using mobile phone technology to assist bystander rescuers in 2010 [14], and the latest ERC guidelines mention a range of new technologies for optimizing dispatcher-assisted CPR (smartphones/speakerphones, video communication, artificial intelligence, and drones) [2]. This would have been unthinkable 35 years ago when the first case of telecommunicator CPR was reported [15]. Technology evolves quickly, and with similar features and capabilities to those of a smartphone (and a similar price to high-end phones) [16], smart glasses could feasibly be incorporated into the dispatch process.

The aim of this study was to determine whether dispatcher assistance with video assistance through smart glasses improves bystander BLS performance in a simulated OHCA compared with telephone instruction only.

2. Method

Experimental pilot study in which volunteers were randomly assigned to an intervention group (dispatcher-assisted BLS with smart glasses-video assistance [SG-VA]) or a control group (dispatcher-assisted BLS with smartphone-audio assistance [SP-AA]).

Students from a Physical Activity and Sports Sciences degree were invited to participate in the study. Inclusion criteria were no theoretical or practical training on BLS in the previous 2 years. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee for Clinical Research of the Catalan Sports Council (reference 022/CEICGC/2021). Signed informed consent was obtained from all participants prior to the study.

The volunteer rescuers received brief training (lasting about 5 min) on dispatcher-assisted calls. Controls were shown how to make calls using the speaker function on a smartphone, while SG-VA participants were shown how to make a video call using smart glasses (Vuzix Blade Upgraded, Vuzix) connected to the VRA Mobile App (Vuzix, USA) [12,13,17] through a 4G wireless network (Fig. 1).

Each participant was asked to deliver emergency care in an OHCA simulation situation with a manikin under the guidance of a member of the research team who was an experienced emergency medical dispatcher blinded to the purpose of the study. The SG-VA rescuers received video assistance through the smart glasses, while the controls received standard telephone assistance through the speaker function of a smartphone.

A member of the research team described the scenario as follows: “A man drops to the ground in front of you. He is this manikin here on the ground. You should act to the best of your ability and you will have the help of an emergency dispatcher.” Participants in the SG-VA group were told “You can contact the emergency dispatcher using the smart glasses you are wearing”, while controls were told that “You can contact the emergency dispatcher using this smartphone.”

The dispatcher guided the participants through the different steps of the BLS protocol and instructed them on how to use the AED and how to

perform high-quality chest compressions according to the ERC guidelines [3]. He adapted his instructions to what he was seeing and/or hearing. The dispatcher was only able to hear the participants in the control group, but in the SG-VA group, he was additionally able to see what the rescuers were seeing on his computer screen thanks to the images streamed through the built-in front-facing camera on the smart glasses. The dispatcher used a metronome to help the rescuers maintain an even chest compression rate of 110 compressions per minute.

The simulation was performed using a resuscitation manikin (Resusci Anne QCPR, Laerdal, Norway) connected to a SimPad PLUS (Laerdal) to record compression quality during 2 consecutive minutes, and an AED Trainer (Laerdal).

We analyzed sociodemographic variables, items in the BLS protocol (assessed dichotomously as performed correctly or incorrectly), chest compression quality, performance times, self-perceptions of performance and confidence for delivering CPR in real-life situations (rated on scale of 0–10, where 10 indicated excellent) and perceived ease of use of the smart glasses (0–10, where 10 indicated very difficult) (Fig. 2).

Statistical analyses were performed in IBM SPSS Statistics software (v.20.Windows) Quantitative variables are described using measures of central tendency (median) and dispersion (interquartile range [IQR]), and qualitative variables as absolute and relative frequencies. Between-group comparisons were performed using the *t*-test (or the Mann-Whitney-*U* test for non-normally distributed variables). Qualitative variables from the BLS protocol were compared using the Chi-square test. Significance was set at $p < 0.05$. Effect sizes were measured for quantitative variables with significant differences using the Cohen's *d* test (or the Rosenthal's *r* test for non-normally distributed variables). They were classified as negligible (<0.2) small (0.2–0.5), medium (0.5–0.8), large (0.8–1.3), or very large (≥ 1.3). The Cramer *V* test was used to calculate the effect sizes for qualitative variables, classified as small (0.1–0.3), medium (0.3–0.5), or large (≥ 0.5).

3. Results

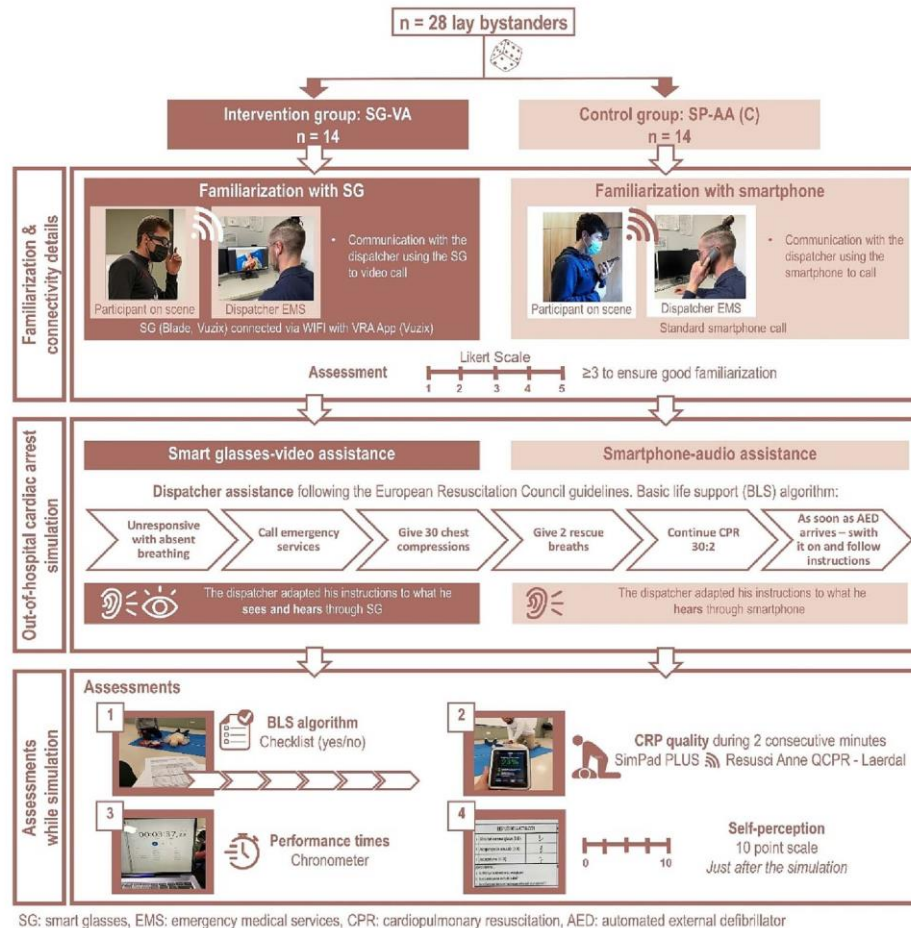
Twenty-eight students, all male, were randomly assigned in equal numbers to the SG-VA group or the SP-AA group. No significant differences were observed for age (SG-VA, 23 years; SP-AA, 23 years; $p = 0.93$), weight (SG-VA, 69 kg; SP-AA, 66 kg; $p = 0.40$), height (SG-VA, 171 cm; SP-AA, 172 cm; $p = 0.45$), or BMI (GI, 22.5 kg/m²; SP-AA, 22.1 kg/m²; $p = 0.62$).

Nine of the 14 participants in the SG-VA group and none of those in the SP-AA group completed the steps of the BLS protocol correctly ($p = 0.003$) (Table 1). Performance in the SG-VA group was significantly better for the following steps: opening the airway (13/14 vs. 5/14, $p = 0.002$), checking breathing (13/14 vs. 8/14, $p = 0.03$), correct AED pad placement (14/14 vs. 6/14, $p = 0.001$), and safety check before shock delivery (12/14 vs. 0/14, $p > 0.001$) (Table 1).

Median (IQR) time to commencement of chest compressions was <2 min in both groups (SG-VA, 113 [104–140] seconds; SP-AA, 119 [93–149] seconds; $p = 0.51$). Median time to shock delivery was <6 min (SG-VA, 332 [314–361] seconds; SP-AA, 334 [297–358] seconds; $p = 0.52$). No significant differences were observed for performance times (Table 1).

The median of mean chest compression depth was suboptimal in both groups (SG-VA, 4.5 [2.9–5.2] cm; SP-AA, 4.4 [3.3–5.5] cm, $p = 0.49$). Median of the mean compression rate was within the recommended range in the SG-VA group and outside it in the SP-AA group (104 [99–106] vs. 98 [93–109] compressions/min, $p = 0.46$) (Table 2). No significant differences were observed for the other quality chest compression metrics analyzed.

Similar median ratings were observed between the groups for self-perceived performance (SG-VA, 5/10 [4–8]; SP-AA, 7/10 [6–7],



SG: smart glasses, EMS: emergency medical services, CPR: cardiopulmonary resuscitation, AED: automated external defibrillator

Fig. 1. Diagram of the study. Intervention group (dispatcher-assisted BLS with smart glasses-video assistance [SG-VA] vs. control group (dispatcher-assisted BLS with smartphone-audio assistance [SP-AA]); familiarization and connectivity details, simulation scenario, and assessments.

$p = 0.17$) and self-perceived confidence for performing CPR in a real-life situation (SG-VA, 7/10 [5–9]; SP-AA, 6/10 [4–7]; $p = 0.06$). Participants in the SG-VA group rated the smart glasses as very easy to use (median score, 2/10 [IQR, 0–3]).

4. Discussion

We designed this pilot study, the first of its kind, to determine whether dispatcher assistance with live video streaming through smart glasses might offer significant advantages over telephone instruction only. Our main findings were that the use of smart glasses was associated with: a) higher rates of correct BLS, b) better use of the AED, and b) faster initiation of CPR. Quality of chest compressions was acceptable in both the SG-VA and SP-AA groups.

Most SG-VA rescuers but none of the controls correctly completed all the steps of the BLS ($p < 0.001$). Correct application of the BLS protocol

on the scene of an OHCA event is crucial for assessing the patient, alerting the emergency medical services, commencing CPR, and ensuring prompt arrival of the AED [3]. Practically all the SG-VA rescuers (13/14) opened the airway properly and checked breathing. In the SP-AA group, just 5 of the 14 rescuers opened the airway and 8 checked breathing. Assessment of breathing, particularly when this is abnormal/agonal, can be difficult for lay people [18,19] and dispatchers on the other end of the telephone [7], but our preliminary findings show that smart glasses could aid this assessment.

Communication via smart glasses was also associated with improved AED use, probably because the dispatcher was able to visually check correct pad positioning and make sure that nobody was touching the patient when the shock was delivered [20,21]. Twice as many SG-VA rescuers correctly positioned the AED pads (12/14 vs. 6/14 in the SP-AA group). Of note, none of the controls warned people to stand back before shock delivery, even though they were instructed

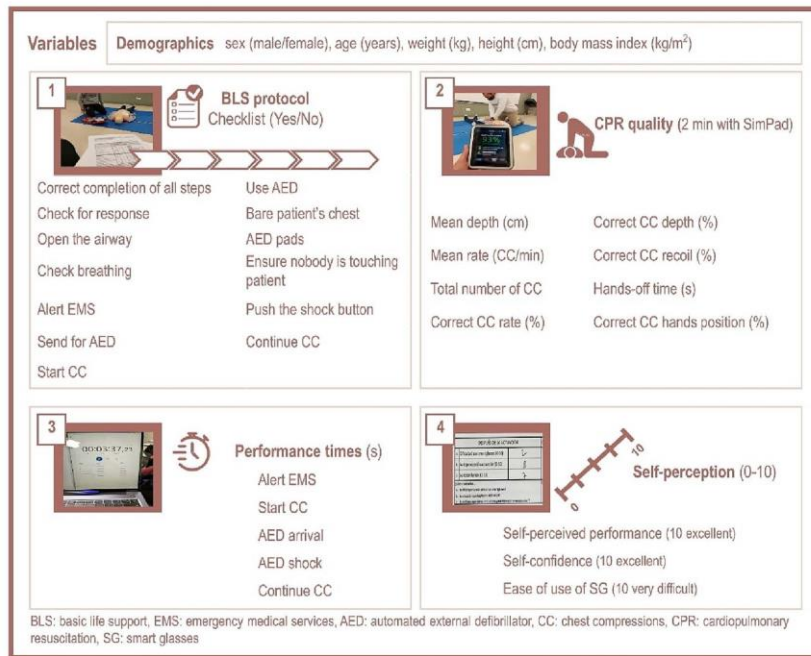


Fig. 2. Sociodemographic variables, BLS protocol, CPR quality, performance times, and self-perceptions.

to do so by the dispatcher, but the vast majority of SA-VG rescuers (12/14) did.

The superior performance observed in the SG-VA group is probably linked to the dispatcher's ability to adapt his instructions to what he was seeing in real time on his computer screen thanks to the images streamed from the front-facing camera on the smart glasses. He would have been able, for example, to see when the rescuer had not performed the head tilt-chin lift maneuver correctly or had wrongly positioned an AED pad. In the SP-AA group, by contrast, he had to rely on what the rescuer was telling him.

When responding to a cardiorespiratory arrest, it is important not only to follow the correct steps, but also to do this quickly, as survival and functional outcomes are time dependent [22]. Lack of experience with smart glasses did not result in any delays in care provision by SG-VA rescuers compared with SP-AA rescuers in our study. A familiarization session of just 5 min was sufficient, and wearers rated the glasses as very being easy to use (with a median score of 2 out of 10). Assessment of performance times is important because previous studies have found that while dispatcher-assisted BLS via a smartphone video call is associated with improved completion of protocol steps, it can result in significant delays [10,23]. This was not the case in our pilot study with life video streaming through smart glasses, but more studies are needed. Our experience suggests that smart glasses result in improved BLS because the lay rescuer can show the dispatcher what he or she is seeing without needing to use his or her hands, which are free to follow the steps in the BLS protocol.

The quality of dispatcher-assisted chest compressions based on the metrics of rate, hand position, and continuity was good in both the SP-AA and SG-VA groups, but chest recoil and compression depth were suboptimal. We believe that the view offered by the smart glasses did not allow the dispatcher to fully appreciate the vertical movement of the rescuer's hands on the patient's chest, preventing proper real-time feedback and guidance. These aspects should be highlighted in dispatcher training.

Our study has several limitations, including the use of a simulated OHCA setting, although it has been shown that at least some of the skills acquired through simulation training are transferred to real practice [24,25]. The generalizability of our findings are also limited as this was a pilot, proof-of-concept study using a sample of 28 physically fit young men conversant with new technology. Although the practicalities of incorporating smart glasses into the dispatch process were not a focus of our study, there are several possibilities. One is that smart glasses will become so ubiquitous that the lay rescuer will already have access to a pair. Another is that they could be delivered by drone (as with other rescue devices) [26] or added to community defibrillator stations and programmed to connect to an emergency dispatcher when picked up.

In conclusion, compared with audio communication over a smartphone, video streaming through smart glasses improved the transfer of dispatcher-bystander information and was associated with better BLS performance and AED use and comparable chest compression quality and performance times. Our findings must be corroborated in larger studies and could lay the groundwork for studies in real-world settings.

Table 1
Completion of basic life support (BLS) steps and performance times in intervention group (dispatcher-assisted BLS with SG-VA) vs. control group (dispatcher-assisted BLS with SP-AA)

| | Intervention group: SG-VA (N = 14) | | Control group: SP-AA (N = 14) | | Significance |
|---|---------------------------------------|-----------|----------------------------------|-----------|--|
| | N | | N | | Chi Square |
| Basic life support protocol (qualitative variables) | | | | | |
| Correct completion of all steps | 9 | | 0 | | $p < 0.001$ (0.69) |
| Check for response | 11 | | 11 | | $p = 1.00$ |
| Open the airway | 13 | | 5 | | $p = 0.01$ (0.60) |
| Check breathing | 13 | | 8 | | $p = 0.03$ (0.41) |
| Send for AED | 14 | | 13 | | $p = 0.31$ |
| Alert EMS | 14 | | 14 | | – |
| Start CC | 14 | | 14 | | – |
| Use AED | 14 | | 14 | | – |
| Bare patient's chest | 14 | | 14 | | – |
| Correctly position AED pads | 14 | | 6 | | $p = 0.001$ (0.63) |
| Ensure nobody is touching patient | 12 | | 0 | | $p < 0.001$ (0.87) |
| Push the shock button | 14 | | 14 | | – |
| Continue CC | 14 | | 13 | | $p = 0.31$ |
| Performance times (quantitative variables) | | | | | |
| | Median | IQR | Median | IQR | Mann-Whitney U test *Student's t-test |
| From the beginning to checkpoints (seconds) | | | | | |
| Checkpoint 1: Alert EMS* | 32 | (15–39) | 36 | (17–56) | $p = 0.25$ |
| Checkpoint 2: Start CC | 113 | (104–140) | 119 | (93–149) | $p = 0.51$ |
| Checkpoint 3: AED arrival* | 238 | (228–259) | 244 | (215–271) | $p = 0.52$ |
| Checkpoint 4: AED shock* | 332 | (314–361) | 334 | (297–358) | $p = 0.52$ |
| Checkpoint 5: Continue CC | 340 | (320–371) | 354 | (309–366) | $p = 0.94$ |
| Time between checkpoints (seconds) | | | | | |
| Alert SME – Start CC* | 91 | (74–108) | 73 | (54–96) | $p = 0.13$ |
| Start CC – AED's arrival | 121 | (120–122) | 123 | (122–124) | $p = 0.001$ (0.61) |
| AED's arrival – AED's shock | 95 | (80–103) | 85 | (80–96) | $p = 0.27$ |
| AED's shock – Continue CC* | 8 | (7–8) | 7 | (7–9) | $p = 0.84$ |

N: Absolute frequencies; IQR: Interquartile range (Q1–Q3); AED: Automated External Defibrillator; EMS, emergency medical services; CC: Chest compressions. Qualitative variables: Chi square test and Cramer's V test for effect size (0.1–0.3, small; 0.3–0.5, medium; ≥ 0.5 , large). Quantitative variables: Mann-Whitney U test and Rosenthal's r test for effect size. *Student's t-test and Cohen's d test for effect size. For Rosenthal's and Cohen's d tests (<0.2, trivial; 0.2–0.5, small; 0.5–0.8, moderate; 0.8–1.3, large; ≥ 1.3 , very large). Significance level: $p = 0.05$.

Table 2
Quality of cardiopulmonary resuscitation in intervention group (dispatcher-assisted BLS with SG-VA) vs. control group (dispatcher-assisted BLS with SP-AA)

| | Intervention group: SG-VA (N = 14) | | Control group: SP-AA (N = 14) | | Significance |
|------------------------------|---------------------------------------|-----------|----------------------------------|-----------|--|
| | Median | IQR | Median | IQR | Mann-Whitney U test *Student's t-test |
| Mean depth (cm)* | 4.5 | (2.9–5.2) | 4.4 | (3.3–5.5) | $p = 0.49$ |
| Mean rate (CC/min) | 104 | (99–106) | 98 | (93–109) | $p = 0.46$ |
| Total number of CCs | 204 | (192–210) | 196 | (182–217) | $p = 0.53$ |
| Correct CC rate (%) | 70 | (38–90) | 31 | (15–87) | $p = 0.30$ |
| Correct CC recoil (%) | 52 | (6–100) | 35 | (1–84) | $p = 0.43$ |
| Correct CC hand position (%) | 100 | (1–100) | 100 | (57–100) | $p = 0.30$ |
| Hands-off time (s) | 1 | (0–2) | 1 | (0–2) | $p = 0.90$ |

N: absolute frequencies; IQR: interquartile range (Q1–Q3); BLS: basic life support; CC: chest compressions. Mann-Whitney U test and Rosenthal's r test for effect size. * Student's t-test and Cohen's d test for effect size. For Rosenthal's r and Cohen's d tests (<0.2, trivial; 0.2–0.5, small; 0.5–0.8, moderate; 0.8–1.3, large; ≥ 1.3 , very large). Significance level: $p = 0.05$.

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CRedit authorship contribution statement

Silvia Aranda-García: Writing – original draft, Supervision, Project administration, Investigation. **Jaime Barrio-Cortes:** Visualization, Resources. **Felipe Fernández-Méndez:** Software, Resources, Investigation. **Martín Otero-Agra:** Writing – review & editing, Formal analysis, Data curation. **Marc Darné:** Investigation, Data curation. **Ernesto Herrera-Pedroviño:** Validation, Resources, Investigation. **Roberto Barcala-Furelos:** Writing – review & editing, Validation, Supervision,

Conceptualization. **Antonio Rodríguez-Núñez:** Writing – review & editing, Project administration, Methodology.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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6.2.2 Article 03 - Title: “Dispatcher, Can You Help Me? A Woman Is Giving Birth”. A Pilot Study of Remote Video Assistance with Smart Glasses.



sensors



Article

“Dispatcher, Can You Help Me? A Woman Is Giving Birth”. A Pilot Study of Remote Video Assistance with Smart Glasses

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Figure 6-3. Screenshot of article 03 identification.
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6.2.2.1 Article abstract

Smart glasses (SG) could be a breakthrough in emergency situations, so the aim of this work was to assess the potential benefits of teleassistance with smart glasses (SG) from a midwife to a lifeguard in a simulated, unplanned, out-of-hospital birth (OHB). Thirty-eight lifeguards were randomized into SG and control (CG) groups. All participants were required to act in a simulated imminent childbirth with a maternal–fetal simulator (PROMPT Flex, Laerdal, Norway). The CG acted autonomously, while the SG group was video-assisted by a midwife through SG (Vuzix Blade, New York, NY, USA). The video assistance was based on the OHB protocol, speaking and receiving images on the SG. The performance time, compliance with the protocol steps, and perceived performance with the SG were evaluated. The midwife’s video assistance with SG allowed 35% of the SG participants to perform the complete OHB protocol.

No CG participant was able to perform it ($p = 0.005$). All OHB protocol variables were significantly better in the SG group than in the CG ($p < 0.05$). Telemedicine through video assistance with SG is feasible so that a lifeguard with no knowledge of childbirth care can act according to the recommendations in a simulated, unplanned, uncomplicated OHB. Communication with the midwife by speaking and sending images to the SG is perceived as an important benefit to the performance.

6.2.2.2 Evidence of Quality

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Full text:

Article

“Dispatcher, Can You Help Me? A Woman Is Giving Birth”. A Pilot Study of Remote Video Assistance with Smart Glasses

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Abstract: Smart glasses (SG) could be a breakthrough in emergency situations, so the aim of this work was to assess the potential benefits of teleassistance with smart glasses (SG) from a midwife to a lifeguard in a simulated, unplanned, out-of-hospital birth (OHB). Thirty-eight lifeguards were randomized into SG and control (CG) groups. All participants were required to act in a simulated imminent childbirth with a maternal–fetal simulator (PROMPT Flex, Laerdal, Norway). The CG acted autonomously, while the SG group was video-assisted by a midwife through SG (Vuzix Blade, New York, NY, USA). The video assistance was based on the OHB protocol, speaking and receiving images on the SG. The performance time, compliance with the protocol steps, and perceived performance with the SG were evaluated. The midwife’s video assistance with SG allowed 35% of the SG participants to perform the complete OHB protocol. No CG participant was able to perform it ($p = 0.005$). All OHB protocol variables were significantly better in the SG group than in the CG ($p < 0.05$). Telemedicine through video assistance with SG is feasible so that a lifeguard with no knowledge of childbirth care can act according to the recommendations in a simulated, unplanned, uncomplicated OHB. Communication with the midwife by speaking and sending images to the SG is perceived as an important benefit to the performance.

Keywords: technology; wearable; telemedicine; midwifery; natural childbirth; lifeguard; smart glasses; emergencies

1. Introduction

In developed countries, unplanned and unattended by midwives out-of-hospital birth (OHB) is a very rare event (0.07% in Spain) [1], which usually occurs because the pregnant woman is far from the health center or because the childbirth is triggered suddenly in

multiparous women [2–4]. The worldwide prevalence of unplanned OHB is estimated to be 0.19–0.61% [5,6]. Of them, 35% occur without medical care and are attended by family members or bystanders (14% by a single person) [4]. Good care for the pregnant woman and the baby in an unplanned OHB can help the mother feel accompanied, have fewer injuries, and the baby to be healthier and prevent disabilities [4,7,8]. Although they are not alarming data, unplanned births are associated with significant perinatal morbidity and mortality [4,5].

Some environments, such as at the beach, with elevated temperatures in warm seasons, may increase the risk of abruption in women whose pregnancies are near or at term [9]. When childbirth occurs on a beach, the lifeguard will have to assist the pregnant woman until the arrival of medical emergency services. Lifeguards are emergency professionals with the duty to assist; they are experts in drowning and have basic knowledge of first aid [10], but they have hardly any knowledge of or experience in childbirth care. Therefore, similarly to other emergencies, as a layperson, he/she may be assisted by telephone through the emergency center [11,12], as has occurred in some OHB (12.5%) [4]. Ideally, the assistance should be carried out by a midwife, who is the health professional in charge of care for women of childbearing age and, specifically, care for physiological childbirth [13,14]. The midwife can assist the lifeguard based on the clinical practice guidelines for OHB that can be extended to first responders who are not experts in childbirth care, such as lifeguards or firefighters [15].

Advances in communication technologies could favor assistance in this type of out-of-hospital emergency by allowing the teleoperator to visualize the situation in real time and communicate with the person providing guidance in the procedures to be carried out [16]. However, remote assistance using smartphones has certain limitations that advise against its use, especially when there is only one intervener, who must manipulate the device at the same time as performing the assistance [11,12,17].

Smart glasses (SG) could be a breakthrough in these scenarios, allowing hands-free communication in real time and the transmission of images and videos from the teleoperator to the layperson [16,18,19]. In this type of telemedicine, defined as “the transfer of skills between health professionals telematically” [20], wearable glasses allow the wearer to read and/or see information (e.g., pictures, videos, checklist, etc.) in the lens of the glasses. The professional can also receive audio communication and complete video calls, which further distinguishes SG as a new device with potentially significant advantages over other devices previously used in telemedicine. To date, very few studies have analyzed the usefulness of this technology in the out-of-hospital setting [21,22], and none have focused on childbirth care or the role of the midwife in telecare.

With the hypothesis that interactive guidance by a midwife visualizing in real time what a layperson transmits to him/her through SG will allow this person to perform the appropriate procedures in a simulated, uncomplicated childbirth, we conducted the present study, whose main goal was to evaluate the possible advantages of this aid.

2. Materials and Methods

2.1. Design

Quasi-experimental randomized pilot study in a simulated scenario.

2.2. Participants

Lifeguards who had studied aquatic lifesaving at a university of physical activity and sports sciences were invited to participate. As inclusion criteria, they must be without theoretical or practical training related to childbirth, and without personal birth experience. Participants with visual impairments incompatible with the use of smart glasses were excluded. Ultimately, 38 lifeguards (9 women, 29 men) aged 22 ± 4 years old, with weight 51–102 kg and height 1.55–1.92 m, were included (Figure 1).

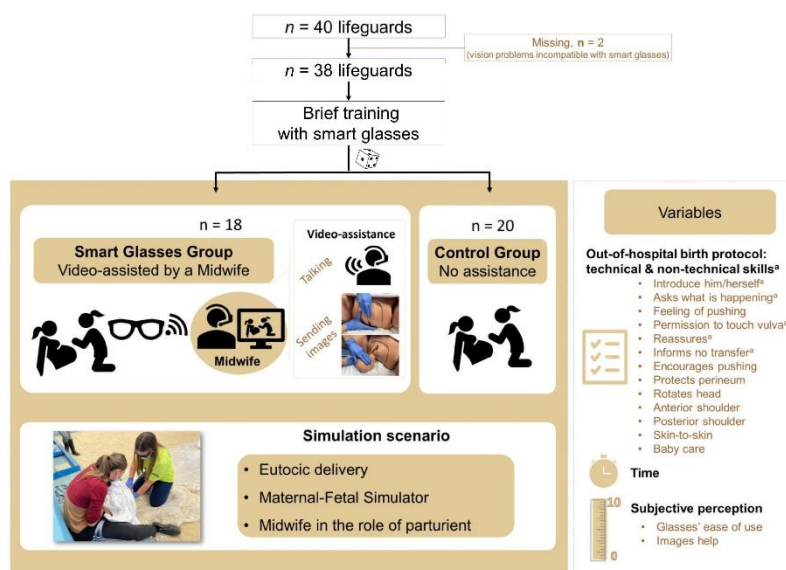


Figure 1. Flowchart design and sample of participants.

2.3. Brief Training on Smart Glasses and Connection Details

Each participant received a brief training with SG to become familiar with this device (Vuzix Blade Upgraded, Vuzix, New York, NY, USA). To ensure adequate familiarization with SG, all participants had to report a perception of the domain in their video call function of 3 or more on a 5-point Likert scale (5: perfect domain). The training was conducted on a simulated beach inside a university building with good internet connection. The SGs were connected via a 4G wireless network to make the video call with the VRA Mobile App (Vuzix, New York, NY, USA).

2.4. Clinical Simulation and Variables

Participants were randomized into the Smart Glasses group (SG: intervention) and the Control Group (CG). All participants had to perform in the same simulation of an imminent eutocic birth away from the hospital. All lifeguards wore smart glasses to record their performance. In addition, the SG group was video-assisted by an expert midwife. CG participants performed without external assistance (Figure 1).

Scenario: An instructor presented the clinical simulation: “A pregnant woman goes into labor on the beach. It is an imminent labor. There is a woman sitting on the ground with a maternal–fetal simulator”. For the SG group, the instructor also said, “You wear the smart glasses, which are connected to a midwife at the control center”, while for the CG group, he said, “You should try to help the laboring woman and the baby with the knowledge you have”. The researcher who handled the maternal–fetal simulator (PROMPT Flex, Laerdal, Norway) was an expert midwife (see Video S1 in Supplementary Material).

The midwife guiding the SG participants through the smart glasses was adapting the assistance based on what she observed and heard from the video call that provided streaming video through the front camera of the glasses. In addition, the midwife projected two images during the third stage of labor that each lifeguard could observe on their smart glasses: one about the placement of the hands for perineum protection and the other showing the anterior shoulder extraction aid (Figure 1).

The following variables were analyzed: (A) total action time (sec); (B) eutocic birth performance protocol measured dichotomously (performed/not performed) and catego-

rizing the variables into technical or non-technical skills (see Figure 1 and Table 1); and (C) subjective perception variables were measured on a scale of 0–10 (ease of use of the smart glasses, with 10 being very difficult [23]), and opinion on whether the photos projected on the smart glasses facilitated the performance (with 10 being very high). The variables of the performance protocol are those stipulated by the clinical practice guideline for OHB [15] (see Table 1).

Table 1. Unplanned out-of-hospital birth sequence, classification into technical or non-technical skills, and description of the variables.

| Unplanned Out-of-Hospital Birth Sequence | Technical Skill | Non-Technical Skill | Skills Description |
|--|-----------------|---------------------|--|
| (1) Introduce him/herself | | x | The lifeguard (L) introduces him/herself to the pregnant woman (P) |
| (2) Asks what is happening | | x | L asks what is happening and how the P is |
| (3) Feeling of pushing | x | | L asks the P if she has a feeling of pushing |
| (4) Permission to touch vulva | | x | L asks the P for permission to examine her vulva |
| (5) Reassures | | x | L reassures the P |
| (6) Informs no transfer | | x | L informs P that childbirth is imminent and she cannot be transferred to a health center |
| (7) Encourages pushing | x | | Expulsive phase (EP): L encourages the P woman to push |
| (8) Protects perineum | x | | EP: L protects the P's perineum with his hands |
| (9) Rotates head | x | | EP: L enables the baby's head to turn |
| (10) Anterior shoulder | x | | EP: L holds the baby to enable the baby's anterior shoulder to come out |
| (11) Posterior shoulder | x | | EP: L holds the baby to enable the baby's posterior shoulder to come out |
| (12) Skin-to-skin | x | | L places the baby skin-to-skin in contact with its mother |
| (13) Baby care | x | | L dries, wraps up, and warms the baby's head and body |

2.5. Data Analysis

Variables were expressed as mean (standard deviation), absolute, or relative frequencies (95% confidence intervals) as appropriate. The Shapiro–Wilk test was used to check the normal distribution of the continuous variables. Paired samples *t*-test or Wilcoxon Signed Rank test were used to compare continuous variables (*t*-test for parametric variables). The chi square test was used to compare dichotomous variables (those variables categorized as performed/not performed). Statistical analyses were performed using SPSS for Windows (v.21.0). Significance was established when $p < 0.05$.

3. Results

No CG participant was able to correctly perform the entire sequence of OHB. However, 35% of the SG participants managed to correctly perform the entire sequence ($p = 0.005$). All variables of the protocol, both technical and non-technical skills, were significantly better in the SG group than in the CG ($p < 0.05$) (Table 1). More than 90% of the SG participants correctly performed 11 of the 13 OHB performance variables. The other two variables were identifying oneself, which was performed by 75%, and placing the newborn skin-to-skin, which was performed by 80%. From the 14 variables of the childbirth assistance protocol, there were 8 that no CG participant (or only one participant) was able to perform (introduce him/herself, ask what is happening, ask about the sensation of pushing, ask permission to touch the vulva, inform that the transfer cannot be performed, actively protect the perineum, place the baby skin-to-skin, and dry and keep the baby warm).

Sixty percent of SG participants correctly performed all technical skills versus 0% of the CG ($p < 0.001$), and 55% of SG participants correctly performed all non-technical skills versus 6% of the CG ($p < 0.001$) (Table 2).

Table 2. Participants in the smart glasses video assistance group and control group who correctly performed the different techniques of the out-of-hospital birth sequence.

| Variable | Description | Smart Glasses | Control | <i>p</i> ^b |
|--|--|---------------|--------------|-----------------------|
| | | <i>n</i> (%) | <i>n</i> (%) | |
| (1) Introduce him/herself ^a | The lifeguard (L) introduces him/herself to the pregnant woman (P) | 15 (75) | 0 (0) | <0.001 |
| (2) Asks what is happening ^a | L asks what is happening and how the P is | 19 (95) | 2 (11) | <0.001 |
| (3) Feeling of pushing | L asks the P if she has a feeling of pushing | 19 (95) | 1 (6) | <0.001 |
| (4) Permission to touch vulva ^a | L asks the P for permission to examine her vulva | 18 (90) | 1 (6) | <0.001 |
| (5) Reassures ^a | L reassures the P | 18 (90) | 9 (50) | 0.007 |
| (6) Informs no transfer ^a | L informs P that childbirth is imminent and she cannot be transferred to a health center | 18 (90) | 0 (0) | <0.001 |
| (7) Encourages pushing | Expulsive phase (EP): L encourages the P woman to push | 19 (95) | 11 (61) | 0.011 |
| (8) Protects perineum | EP: L protects the P's perineum with his hands | 18 (90) | 0 (0) | <0.001 |
| (9) Rotates head | EP: L enables the baby's head to turn | 20 (100) | 8 (44) | <0.001 |
| (10) Anterior shoulder | EP: L holds the baby to enable the baby's anterior shoulder to come out | 19 (95) | 12 (67) | 0.024 |
| (11) Posterior shoulder | EP: L holds the baby to enable the baby's posterior shoulder to come out | 20 (100) | 11 (65) | 0.004 |
| (12) Skin-to-skin | L places the baby skin-to-skin in contact with its mother | 16 (80) | 0 (0) | <0.001 |
| (13) Baby care | L dries, wraps up, and warms the baby's head and body | 19 (95) | 2 (11) | <0.001 |
| Complete sequence | | 7 (35) | 0 (0) | 0.005 |
| All technical skills | | 12 (60) | 0 (0) | <0.001 |
| All non-technical skills ^a | | 11 (55) | 1 (6) | <0.001 |

^a non-technical skill, ^b significance according to chi-square.

The performance time of all simulations was less than 5 min (CG: 117 ± 32 s, SG: 178 ± 37 s, *p* = 0.03). The SG participants reported that the difficulty of using the glasses was low (1.2 out of 10) and that the photos projected through the smart glasses made the performance much easier (8.6 out of 10) (Table 3).

Table 3. Perceptual variables of competence, confidence, difficulty using the smart glasses, and image reception.

| | Smart Glasses | Control | <i>p</i> |
|-----------------------------------|---------------|--------------|----------|
| | <i>n</i> (%) | <i>n</i> (%) | |
| Self-reported level of competence | 6.8 ± 1.5 | 3.8 ± 1.8 | <0.001 |
| Self-reported level of confidence | 7.0 ± 1.4 | 3.3 ± 2.9 | <0.001 |
| Difficulty using smart glasses | 1.2 ± 2.0 | - | - |
| Images facilitate the help | 8.6 ± 2.1 | - | - |

4. Discussion

The potential of telemedicine is continually expanding, although additional evidence is needed before its incorporation into routine practice [24,25]. The scarce scientific evidence on the use of SG-dispatcher in out-of-hospital emergencies is limited to the field of triage [21,22]. In this sense, our study, whose aim was to assess the impact of the use of SG on the quality of care for a specific acute out-of-hospital event, in our case an uncomplicated birth, provides novel and relevant information.

Our major finding was that when the midwife video-assisted with SG, the lay rescuer in childbirth assistance is able to correctly perform the protocol for unplanned, uncomplicated

OHB. When a birth occurs in an unplanned way, a process that should be natural can become an emergency with relevant risks for the mother and the baby [4]. Although rare, it is a reality that unplanned OHBs do occur, and providing a means that may help bystanders to perform better immediate care might improve mother and baby outcomes. Based on our findings, video assistance with SG guided by a midwife could be good assistance for laypeople naïve in this type of event, even if they have some duty to assist (e.g., lifeguards, police, firefighters, etc.).

It has been verified that with the video assistance, the participants were able to correctly follow the sequence of actions and perform the different recommended steps even though it was the first time they had done so. Improvements in video-assisted performance with SG occurred in both technical and non-technical skills. The technical skills are those directly related to procedural birth assistance. Without the help of a childbirth professional expert in these skills, it would be difficult to provide good care for both mother and baby. Non-technical skills are those related to communication and human care, in which the help of the midwife is not indispensable but is desirable, as these skills are essential in the management of this stressful situation.

Regarding technical skills, the video-assisted lifeguards with SG performed significantly better than the CG. This includes aspects related to the assessment of the stage of labor, assistance during the expulsive phase, and newborn care.

When the midwife at the emergency center realized that this was an unplanned OHB situation, he/she guided the lifeguard to ask about the pushing feeling, assess the stage of labor, encourage pushing in the third stage of labor, and protect the perineum. Many vaginal deliveries are accompanied by perineal trauma, which is associated with significant short- and long-term morbidity with pain, urinary or fecal incontinence, and dyspareunia [26–28]. Active protection of the perineum is an extended practice to reduce perineal injury [29] recommended by the World Health Organization [30] and current protocols [31,32]. In our study, the midwife's SG-dispatcher allowed 90% of the participants with SG to correctly protect the perineum compared to 0% of those who acted autonomously.

Once the third stage of labor has ended, newborn care is essential. In the proposed setting, hypothermia used to be the most common morbidity, occurring in 50% of unplanned OHBs [33]. The wet newborn can lose temperature rapidly by evaporation and conduction [34]. Therefore, a good strategy to prevent hypothermia is to place the baby skin-to-skin on the mother's bare chest and/or abdomen, then dry and cover him/her [34,35]. It is also advisable to place the baby skin-to-skin for additional benefits (successful breastfeeding, cardiorespiratory stability, and maternal–filial bonding) [36]. In our study, the vast majority (80%) of participants with SG placed him/her skin-to-skin and almost all dried and covered the baby's body and head. However, none of the CG participants placed the newborn skin-to-skin, and only one dried and covered the baby.

Regarding nontechnical skills, the lifeguards without assistance with SG did not have effective communication with the pregnant woman: they did not speak to the pregnant woman to identify themselves, nor explain the situation, nor did they ask for permission to touch the vulva, and only half of them reassured the woman. However, with the SGs, the midwife was able to video-assist the rescuers, and nearly all of them performed the non-technical skills perfectly. Although in unplanned OHB the woman may feel confident, empowered, and exhilarated, communication and reassurance are especially important because expectant mothers report fear, and worry about poor interpersonal skills of the people assisting them [7,37]. This, added to the fact that pregnant women often report lack of consent for certain procedures such as vulvar assessment or active protection of the perineum [7,37], has led scientific societies to urge effective and empathic communication with the women [38,39]. Care providers should be aware of the importance of tone, behaviors, and the words they use for effective communication, ref [38,39] as was the case in the first responders with SG thanks to the video assistance of the midwife who encouraged better accompaniment of the woman in this simulated vital moment. These non-technical skills are fundamental for the respectful accompaniment of the woman so

that the experience of childbirth can be positive and empowering instead of negative and traumatizing [40,41].

The positive results of the intervention group throughout the protocol can be explained by the good communication between the rescuer and the midwife through the SG. The midwife was able to guide and correct the rescuer based on what she saw/heard in the video call. This communication with SG helped the vast majority of SG participants to perform most of the required skills well. In addition to verbal instructions, the midwife also sent images so that the rescuers could see how they should assist in the third stage of labor (placing their hands to protect the perineum or to facilitate the extraction of the baby's shoulders). These images were projected onto the lens of the SG themselves, and participants stated that they were very helpful ($8.6 \pm 2.1/10$) to facilitate understanding how they should position their hands to assist the pregnant woman. In addition, participants stated that the use of the smart glasses' technology was of very low difficulty (1.2/10).

Without the video assistance, the lifeguards, who were laypeople in childbirth care, could barely help in unplanned, uncomplicated OHB. Some of the participants were able to perform isolated actions that could be considered innate or transversal to any emergency situation, such as reassuring the pregnant woman, or accompanying in certain aspects of the expulsive phase instinctively, such as holding the baby's head and shoulders in the expulsive phase.

In our pilot study, we have verified how telemedicine with images through SG can be a powerful communication device in which a midwife can remotely video-assist a lay person in an eutocic birth. In the field of unplanned OHB, this becomes even more interesting when they are assisted by a single person, which represents 14% of these deliveries [1], because SG allow hands-free, remote assistance. Based on our results, it could be interesting to study the incorporation of this type of new communication technology, especially in those places where delayed times are expected in the arrival of emergency services (for example: remote places such as rural areas, fishing boats, or airplanes, far from the ambulance and hospital). Although the future implementation of this technology may represent a great opportunity to improve assistance in emergencies attended by laypeople, it will also represent a challenge in its implementation. It will be necessary to take into account the opinion of the dispatcher, the first responder, and the patient (in this case, the pregnant woman) for the acceptability of this technology. In addition, relevant ethical aspects related to privacy, security, equity, and responsibility must be taken into account to respect the rights of people [42].

This study has some limitations. The emergency was simulated, which entails its specific limitations by design. Although the simulated pregnant woman was a midwife manipulating a maternal–fetal simulator in an attempt to make it as realistic as possible, these results cannot be directly extrapolated to a real situation. The use of this type of telemedicine requires good connectivity, which may limit its use in remote locations or in some areas of buildings with poor internet connection (e.g., basements, etc.). The type of birth chosen was eutocic, in which there were no complications for the pregnant woman or the baby, and we do not know the extent of the usefulness of this type of midwife-assisted telemedicine in other types of deliveries. Our findings are contextualized with a specific typology of participants (lifeguard workers, young people, university students, laypeople in childbirth assistance), so they cannot be extrapolated to other profiles such as other health professionals or people with a low proficiency with communication technologies. Also, our study did not compare classic telephone vs. smart glasses assistance in childbirth, an investigation that should be done in the future.

5. Conclusions

In simulated, unplanned, uncomplicated, remote birth conditions, telemedicine through video assistance with SG is feasible for a lifeguard with no knowledge of childbirth care to perform according to the recommendations for unplanned, out-of-hospital birth. The communication of the midwife with the lay attendant by talking and sending images

to the SG may be of significant benefit both in relation to technical (steps of the recommended sequence) and non-technical skills (support to the laboring woman). The SGs are easy to use, with a minimal learning period, although they require good internet connection, which may be a limitation in remote locations or those with poor coverage. More studies are needed to ascertain the contribution of SG to telemedicine in out-of-hospital emergency care.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/s23010409/s1>, Video S1: Lifeguard assisting an imminent childbirth with the help of a midwife through smart glasses.

Author Contributions: Conceptualization, S.A.-G., R.B.-F., A.R.-N. and M.S.-F.; methodology, S.A.-G., R.B.-F., A.R.-N. and M.P.R.; software, M.S.-F., F.F.-M., E.H.S. and L.V.-V.; validation, M.S.-F. and F.F.-M.; formal analysis, A.R.-N. and M.P.R.; investigation, R.B.-F., M.S.-F., F.F.-M., M.P.R., E.H.S., L.V.-V. and S.S.R.-M.; resources, R.B.-F., M.S.-F., F.F.-M., M.P.R. and E.H.S.; data curation, S.A.-G.; writing—original draft preparation, S.A.-G. and M.S.-F.; writing—review and editing, S.A.-G., R.B.-F., A.R.-N., M.S.-F., M.P.R., E.H.S., L.V.-V. and S.S.R.-M.; visualization, M.P.R., E.H.S., L.V.-V. and S.S.R.-M.; supervision, R.B.-F. and A.R.-N.; project administration, S.A.-G., R.B.-F. and A.R.-N. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Sports Sciences (University of Vigo, reference number 02-1421).

Informed Consent Statement: Written informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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Supplementary materials:

The following supporting information can be downloaded at:

[https:// www.mdpi.com/article/10.3390/s23010409/s1](https://www.mdpi.com/article/10.3390/s23010409/s1), or
<https://x.com/silviaaranda46/status/1612755484230008832?s=20>

Video S1: Lifeguard assisting an imminent childbirth with the help of a midwife through smart glasses.



6.3 AUGMENTED REALITY TRAINING WITH SMART GLASSES IN BLS

Article 04 (letter to editor) - Title: Augmented reality smart glasses. A new resuscitation training tool or a worthless gadget?

Article 05 - Title: Augmented reality training in basic life support with the help of smart glasses. A pilot study.

Article 06 - Title: New communication tool for basic life support training: smart glasses. A quasi-experimental study.



6.3.1 Article 04 (letter to editor) – Title: Augmented reality smart glasses. A new resuscitation training tool or a worthless gadget?

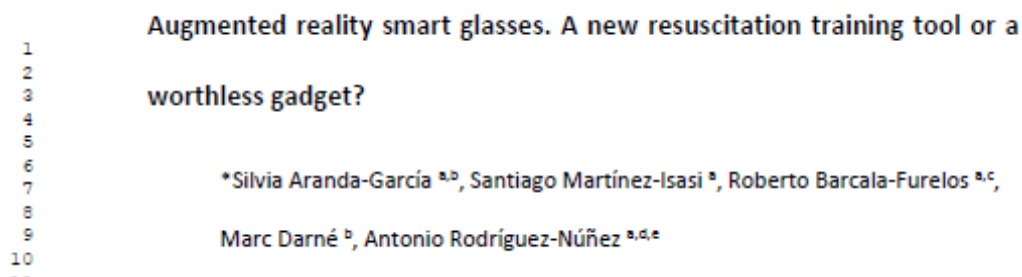


Figure 6-4. Screenshot of article 04 (letter to editor) identification.

6.3.1.1 Evidence of Quality

This letter to the editor was published in *Internal and Emergency Medicine* (ISSN: 1828-0447, Publisher: *Springer*). It is cataloged in the Web of Science and Scopus repositories in the field of *Medicine, general & internal*.

Impact factor and quartiles:

| Indexing database | Impact Factor | Quartile | Category |
|-------------------------------|---------------|----------|------------------------------|
| Journal Citation Report (JCR) | 4.6 | Q2 | Medicine, general & internal |
| SCImago Journal Rank (SJR) | 0.93 | Q1 | Emergency medicine |

Since its acceptance (October 31, 2023) up to the present moment (November 6, 2023) this publication has not been cited.

Full citation of the manuscript:

Silvia Aranda-Garcia, Santiago Martínez-Isasi, Roberto Barcala-Furelos, Marc Darné Antonio Rodríguez-Núñez. **Augmented reality smart glasses. A new resuscitation training tool or a worthless gadget?** *Intern Emerg Med.* 2023. [manuscript accepted October 31]

Specific contribution of the PhD candidate to the article:

Leadership in writing the manuscript (first author). Conception and design of the idea of the letter to the editor, drafting of the manuscript and revision after peer-review.

Full text:

Augmented reality smart glasses. A new resuscitation training tool or a worthless gadget?

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The use of new training technologies that enhance learning, such as augmented and/or virtual reality, has been proposed to effectively train the general population in basic life support (BLS) [1]. However, its specific role for this purpose has yet to be explored in depth [2]. In a preliminary study, our research group reported on the potential of augmented reality through video calls with smart glasses for BLS training, reinforced by the shared vision between an instructor and a student [3]. In this type of individualized remote training, the student wears smart glasses that are connected via WiFi to the instructor [4]. Both individuals telecommunicate in real-time through audio and video via the wearable device, which is equipped with a front camera and streams everything the student encounters (such as manikin body parts and devices) and their actions (including chest compressions and the placement of defibrillator pads). This allows the instructor to “immerse” themselves in the student’s mind and, in consequence, adapt the training and feedback based on what he/she hears and sees on his/her computer, tablet, or smartphone [3]. The trainer can also send additional graphic information to be displayed on the mini-screen of the smart glasses. This may include images, GIFs, videos related to casualty assessment or resuscitation skills. Our group has successfully employed this feature in a previous study, where a midwife provided tele-assistance to a lifeguard, enabling them to effectively

simulate an unplanned out-of-hospital childbirth [5]. This way, students could learn not only from what the instructor explains to them but also by visually observing figures, images, videos, or animated demonstrations of key techniques, such as opening the airway or positioning themselves to perform chest compressions (Figure 1).

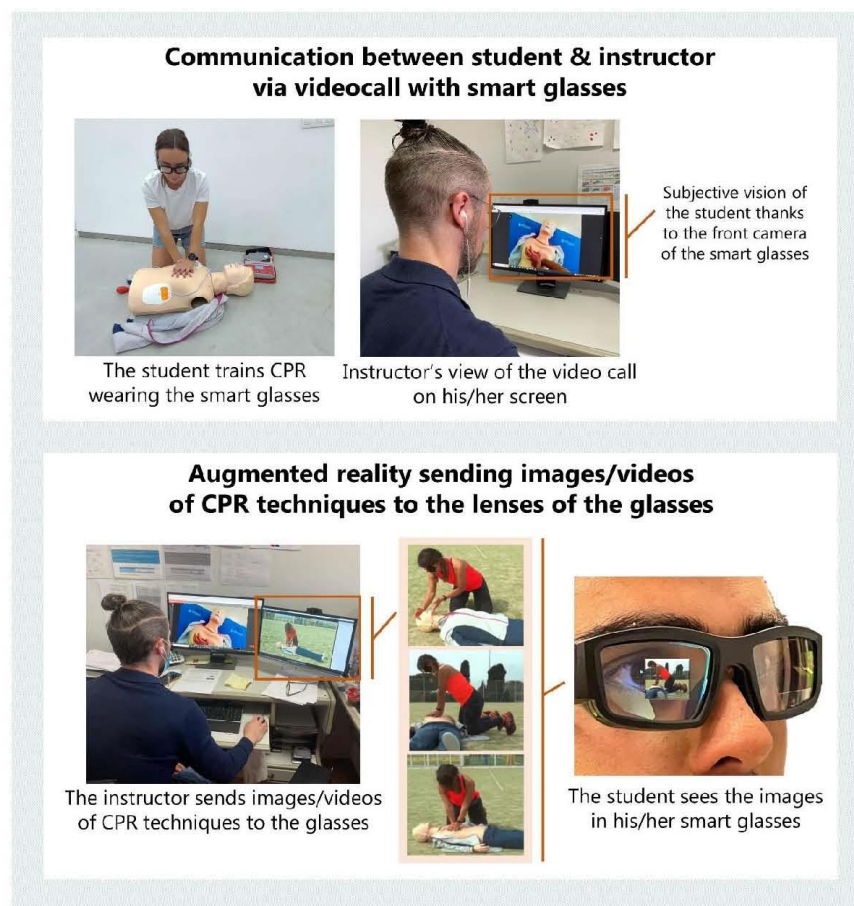


Figure 1. Augmented reality with smart glasses. A new tool for CPR training? Possibilities offered by augmented reality with smart glasses for cardiopulmonary resuscitation training.

Furthermore, as a wearable methodology, smart glasses offer the advantage of not requiring the user to hold the device while in use. This allows the student to keep their hands completely free to practice the various skills recommended in the event of a cardiorespiratory arrest, which

is expected to enhance training dynamics and facilitate two-way communication between the trainer and the student.

In another context, there are remote locations where access to BLS training can be challenging, particularly in rural characterized by low population density and considerable distances from urban centers. In such isolated regions, where the presence of resuscitation instructors is limited or non-existent, tele-training options like this could enable bystanders to access BLS education. To make this form of telecommunication feasible, all that would be required are smart glasses (already available on the market and accessible to the public at a lower cost than high-end smartphones) equipped with a video call App and standard WiFi connectivity.

In summary, we believe that BLS training, supported by augmented reality through video calls with smart glasses, is a currently available and feasible methodology that should be considered in certain scenarios, alongside traditional BLS training methods.

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6.3.2 Article 05 – Title: **Augmented reality training in basic life support with the help of smart glasses. A pilot study.**



Figure 6-5. Screenshot of article 05 identification.

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6.3.2.1 Article abstract

Introduction: Laypeople should be trained in basic life support and traditional and innovative methodologies may help to obtain this goal. However, there is a knowledge gap about the ideal basic life support training methods. Smart glasses could have a role facilitating laypeople learning of basic life support. **Aim:** To analyze the potential impact on basic life support learning of a very brief training supported by smart glasses video communication. **Methods:** Twelve laypeople were basic life support tele-trained by means of smart glasses by an instructor in this pilot study. During training (assisted through smart glasses) and after the training (unassisted) participants' performance and quality of basic life support and automated external defibrillation procedure were assessed on a standardized simulated scenario. **Results:** After the training all participants were able to deliver good quality basic life support, with results comparable to those obtained when real time remotely guided by the instructor through the smart glasses. Mean chest compression rate was significantly higher when not guided (113 /min vs. 103 /min, $p = 0.001$). When not assisted, the participants spent less time delivering the sequential basic life support steps than when assisted while training. **Conclusions:** A very brief remote training supported by instructor and smart glasses seems to be an effective educational method that could facilitate basic life support learning by laypeople. This technology could be considered in cases where instructors are not locally available or in general in remote areas, providing basic internet connection is available. Smart glasses could also be useful for laypeople rolling-refreshers.

6.3.2.2 Evidence of Quality

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Simulation and education

Augmented reality training in basic life support with the help of smart glasses. A pilot study



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Abstract

Introduction: Laypeople should be trained in basic life support and traditional and innovative methodologies may help to obtain this goal. However, there is a knowledge gap about the ideal basic life support training methods. Smart glasses could have a role facilitating laypeople learning of basic life support.

Aim: To analyze the potential impact on basic life support learning of a very brief training supported by smart glasses video communication.

Methods: Twelve laypeople were basic life support tele-trained by means of smart glasses by an instructor in this pilot study. During training (assisted through smart glasses) and after the training (unassisted) participants' performance and quality of basic life support and automated external defibrillation procedure were assessed on a standardized simulated scenario.

Results: After the training all participants were able to deliver good quality basic life support, with results comparable to those obtained when real time remotely guided by the instructor through the smart glasses. Mean chest compression rate was significantly higher when not guided (113/min vs. 103/min, $p = 0.001$). When not assisted, the participants spent less time delivering the sequential basic life support steps than when assisted while training.

Conclusions: A very brief remote training supported by instructor and smart glasses seems to be an effective educational method that could facilitate basic life support learning by laypeople. This technology could be considered in cases where instructors are not locally available or in general in remote areas, providing basic internet connection is available. Smart glasses could also be useful for laypeople rolling-refreshers.

Keywords: Learning, Laypeople, Smart Glasses, Cardiac arrest, Resuscitation, Remote area, Telemedicine

Introduction

According to EuReCa TWO study, the overall incidence of out-of-hospital cardiorespiratory arrest where cardiopulmonary resuscitation (CPR) was attempted is 56 per 100,000 population per year (range: 21–91).¹ In this prospective study, in which data from 28 European cities are analyzed, CPR was started before the arrival of emergency medical services in 58% of the cases, and the rate of survival was twice as high when CPR was started by a bystander as when was started by emergency medical services.¹

Teaching basic life support (BLS) to the general population is key to improve bystander immediate resuscitation attempts and survival rates in the event of out-of-hospital cardiorespiratory arrest.^{1–2} Several traditional educational methodologies have proven to be effective

for laypeople to be competent by applying the BLS protocol, using the automated external defibrillation (AED), and performing quality resuscitation.³ According to the systematic review by González-Salvado et al., there is great heterogeneity in the research designs on BLS training in laypeople.³ There is an apparent advantage of instructor-led methods with the practice of resuscitation skills, there seems to be a trend towards short training sessions, and practically all the designs evaluate the protocol of BLS and the quality of resuscitation. However, the ideal methodology to learn and retain the knowledge and skills to act in the event of a cardiorespiratory arrest remains unknown.⁴ In order to achieve the goal that most people be trained and be able to resuscitate with enough quality, it seems necessary to explore new methodologies and technologies.⁵

Thus, in the 2021 guidelines of the European Resuscitation Guidelines (ERC) it is advised to use technology to improve educa-

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tion by teaching resuscitation and engaging as many learners as possible.⁴ The use of technology in BLS training programs can, for example, promote better resuscitation learning with the real-time feedback system,⁶ make learning more attractive, or make it possible for teaching to reach more remote places with telematic training.^{7–10}

Among the new communication technologies used in skills training we can find smart glasses. This wearable has features similar to a smartphone, for example, one can make a video call to communicate by audio and video with another person by connecting with his/her computer, tablet, or smartphone. Communication between student and teacher by video call with smart glasses has been used in the hospital setting to video assist a surgeon or to show a surgical procedure in the medical classroom,^{11–12} or in the extra-hospital setting to video assist an unplanned childbirth.¹³ However, it is unknown if this type of communication with this wearable would be effective and interesting for teaching the BLS in an out-of-hospital setting with laypeople.

Therefore, our objective of this pilot study was to analyze the potential impact on BLS learning of very brief training based on experiencing a performance in simulated cardiac arrest and with the support of smart glasses video communication in laypersons.

Methods

Participants

Twelve University students of the Degree in Physical Activity and Sports Sciences were invited to participate as a convenient sample for this pilot study. To be included, it was necessary for participants not to have received BLS training for the two years prior to the study, nor have physical impediments to perform chest compressions, nor have vision or hearing problems incompatible with video call communication from smart glasses.

Each individual signed an informed consent before his/her voluntary participation. This study has been approved by the Ethics Committee for Clinical Research of the Catalan Council (reference number 026/CEICG/2022).

Procedures and training

Each participant was familiarized with the smart glasses, then trained in a simulated cardiac arrest scenario with an instructor who taught them via video call using smart glasses, and then performed autonomously in a simulated cardiac arrest. The performance of each participant was evaluated twice: first test while training assisted with smart glasses (M1), and the second test once the training was finished as post-test without assistance of smart glasses (M2) (Fig. 1).

Familiarization with smart glasses and connectivity

Before the training, each participant became familiar with the basic functions of the smart glasses in their use of video calls (turn on glasses, enter the App, make calls, hang up/drop off video calls) in a short training < 5 minutes. A score of at least 3 points on a 5-point Likert scale was required after this training to ensure proper familiarization with the smart glasses.

The smart glasses (Vuzix Blade Upgraded, Vuzix, US) had the Vuzix Remote Assist App (VRA App) installed, which allows making video calls with another device, in this case with a laptop connected to the web page of the application (<https://vra.vuzix.com>). The smart glasses were connected via WIFI 4G as described in a previous study.¹³ The participant communicated with the instructor by video

call with the smart glasses (voice and streaming the images captured by the front camera). The instructor could talk and view real-time video on his computer. The instructor was a member of the research team blinded to the study's purpose.

BLS training

Each participant underwent BLS training in a simulation scenario. The training consisted of attending a simulated cardiac arrest with the remote assistance of an instructor in the role of an emergency medical services' dispatcher. The instructor was tele-assisting based on the BLS protocol of the ERC.¹⁴ Being connected via video call with the smart glasses, the instructor could correct the student based on what he/she heard and saw through the smart glasses.

A member of the research team presented the following simulation training scenario: "This man has collapsed in front of you. He is this doll that's on the ground. You must act to the best of your ability and you have the help of an instructor from the emergency medical services who is seeing the same things you see. You can contact the instructor through the smart glasses you are wearing while making the video call as you already know".

The training was carried out on a resuscitation manikin (Resusci Anne QCPR, Laerdal, Norway) connected to SimPad PLUS to record resuscitation quality (Laerdal, Norway). In the simulation, an investigator brought in the AED (AED trainer, Laerdal, Norway) when the participant completed two consecutive minutes of chest compressions.

Assessments and variables

The evaluations of M1 (just while training with smart glasses) and M2 (unassisted alone post-test) recorded: A) the BLS performance protocol measured with a checklist and noting whether or not each step was carried out correctly (following the standards established by ERC in its guides published in 2021),¹⁴ B) quality of chest compressions for two consecutive minutes measured with the Simpad (Laerdal, Norway), C) performing times, and self-perception variables measured on a scale of 0 to 10 (Fig. 2).

Data analysis

All analyses were performed with the IBM SPSS Statistics version 21 for Windows software (Armonk, NY, USA). Quantitative variables were described through measures of central tendency (median) and dispersion (interquartile range-IQR). The qualitative variables were described through absolute and relative frequencies. For the comparisons of the quantitative variables, the Wilcoxon's signed ranked test or the Student's t test were used, depending on the normality criteria (Shapiro-Wilk test). For the Effect Size, the Rosenthal's r test or the Cohen's d test were used respectively. To define the effect size, the following classification was used: < 0.2: Trivial / 0.2–0.5: Small / 0.5–0.8: Moderate / 0.8–1.3: Large / > 1.3: Very large.^{15–16} For the comparisons of the qualitative variables, the McNemar test was used. The level of statistical significance was established when $p < 0.05$.

Results

Demographics

Participants had a median age of 23 years (IQR: 20–29), weight of 66 kg (IQR: 58–76), height of 170 cm (IQR: 166–177) and Body Mass Index of 22.5 kg/m² (IQR: 21.9–24.6). 67% of the participants were men.

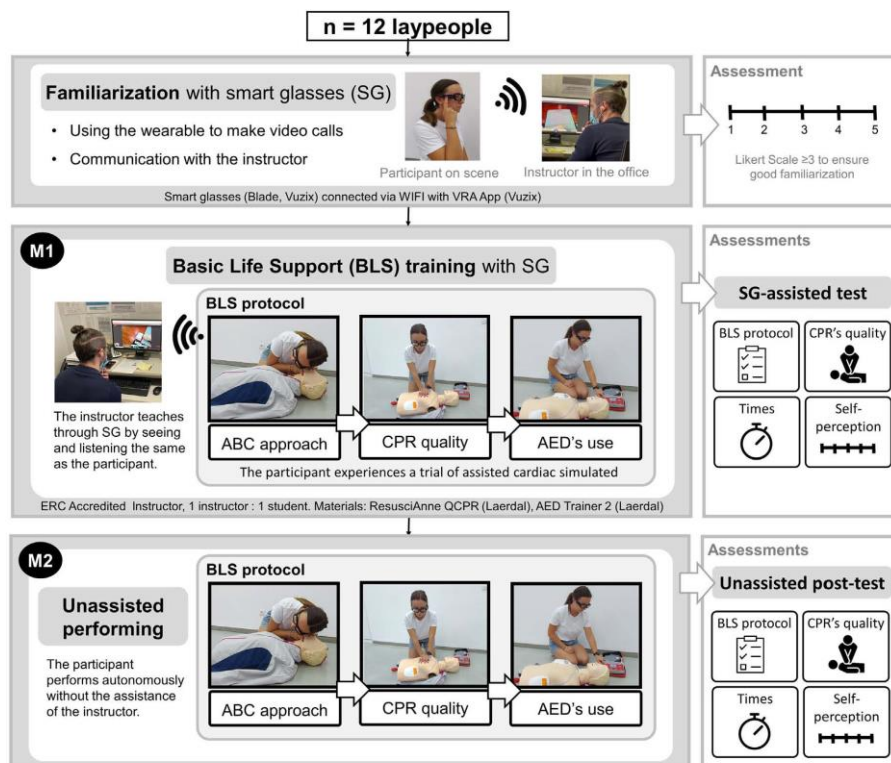


Fig. 1 – Participants' flowchart and study design scheme.

BLS protocol

The test carried out while the participants were trained through the smart glasses (M1) showed how all or nearly all of them performed the steps of the BLS sequence following ERC guidelines (Table 1). That means that all participants did correctly ask for an AED, call 112, start chest compressions, bring the AED, bare victim's chest, place AED pads correctly, perform an effective defibrillation, and restart chest compressions; all except one participant did correctly open victim's airway, check victim's breathing, and warn before defibrillation; and 9 out of 12 of them checked the victim's response correctly. Otherwise, the test carried out after the training (M2 without assistance) showed that less participants than in M1 performed correctly the different steps of BLS sequence (Table 1). However, those differences were not statistically significant ($p > 0.05$). In M1 and M2, all the participants managed to make the call to 112, began the chest compressions and stripped the victim's chest before placing the AED when performing the Unassisted post-test. Only one of the participants did not use the AED or apply effective defibrillation in M2.

Quality of resuscitation (chest compressions only)

The median and interquartile range of the variables related to the quality of chest compressions in M1 and M2 can be seen in Table 2. The median of the mean depth variable for both tests were around

4 cm (no chest compressions with good depth), the median of the mean rate variable was 103 chest compressions/min in M1 and 113 chest compressions/min in M2, and always with de hands placed in correct compression point (in M1 and M2). No significant differences were observed between M2 and M1 in CPR quality (4%; IQR: 0–50 vs 7%; IQR: 1–68) or in the rest of the CPR variables studied, except for the mean rate of CC, which was significantly lower in M1 than in M2 (M1: 103 chest compressions/min, IQR: 98–107; M2: 113 chest compressions/min, IQR: 107–122; $p = 0.001$; effect size = 1.52).

Performing times

The median and interquartile range of the variables related to the performance times in M1 and M2 can be seen in Table 3. In M1, the time from start to call 112 was 35 seconds (IQR: 21–44), time to the first chest compression 124 seconds (IQR: 106–153), and the time to defibrillation 332 seconds (IQR: 319–372). Otherwise, in M2, the time from start to call 112 was 25 seconds (IQR: 15–63), to the first chest compression was 61 seconds (IQR: 48–78), and to defibrillation was 240 seconds (IQR: 233–262). There were no differences between M1 and M2 in the performing time from the start of the scenario until the call to 112, nor from the discharge of the AED to the restart of the chest compressions (Table 3). However, a significantly shorter time was observed in M1 to start the chest

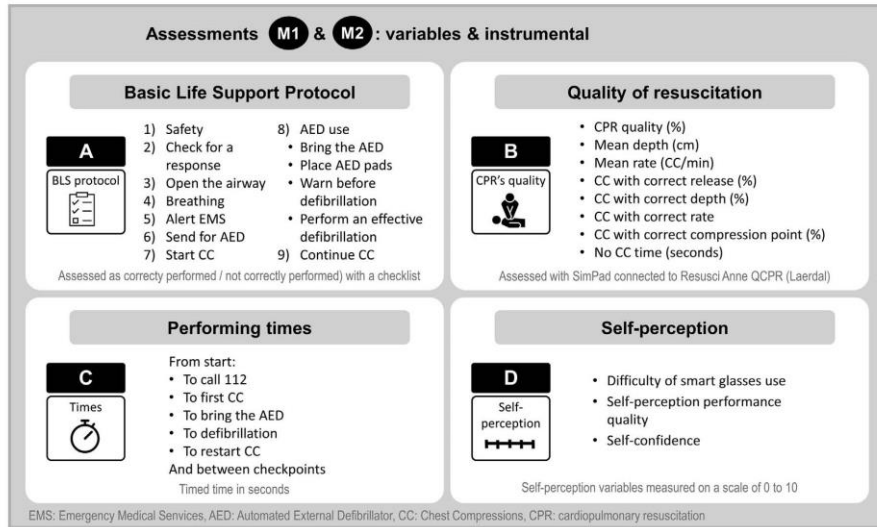


Fig. 2 – Variables and measuring instruments of both assessments: M1 (just while training with smart glasses) and M2 (Unassisted post-test).

Table 1 – Performance of the BLS sequential steps by participants, while instructor-smart glasses assisted (M1) during training and when alone after the training (M2). (N = 12).

| | M1: while training with smart glasses | M2: Unassisted post-test | Significance |
|-------------------------------------|---------------------------------------|--------------------------|--------------|
| | N | N | |
| Check victim's response | 9 | 7 | $p = 0.69$ |
| Open victim's airway | 11 | 8 | $p = 0.25$ |
| Check victim's breathing | 11 | 10 | $p = 1.00$ |
| Ask for an AED | 12 | 9 | $p = 0.25$ |
| Call 112 | 12 | 12 | - |
| Start chest compressions | 12 | 12 | - |
| Bring the AED | 12 | 11 | $p = 1.00$ |
| Bare victim's chest | 12 | 12 | - |
| Place AED pads | 12 | 11 | $p = 1.00$ |
| Warn before defibrillation | 11 | 7 | $p = 0.13$ |
| Perform an effective defibrillation | 12 | 11 | $p = 1.00$ |
| Restart chest compressions | 12 | 11 | $p = 1.00$ |

AED: Automated External Defibrillator. N: Absolute frequency.

compressions (both from the start of the scenario and from the 112 call to the start of the chest compressions), to bring the AED (both from the start of the scenario and from finishing the chest compressions), to the defibrillation, and in the total time of the scenario that ended when restarting the chest compressions after the shock (Table 3). This last difference was approximately one and a half minutes between M2 (249 s; IQR: 241–270) and M1 (340 s; IQR: 324–381; $p = 0.062$; effect size = 0.62).

Self-perceptive variables

Participants reported higher self-perception of performance quality in M2 (7.0; IQR: 6.0–7.8) than in M1 (5.5; IQR: 4.3–8.0; $p = 0.020$; effect size = 0.55) (Table 4). However, there were no differences in

the difficulty of using the smart glasses or in their self-confidence during the performance.

Discussion

Teaching BLS to as many laypeople as possible is an aspiration to prevent the consequences of out-of-hospital cardiac arrest. In some cases, and environments, it can be difficult to access this type of education, which is why it may be interesting to explore training with new technologies. However, the new technological tools, such as augmented reality, should not be used without a previous rigorous evaluation of their feasibility, advantages, and disadvantages. For

Table 2 – Quality of cardiopulmonary resuscitation (CPR) during assisted training with smart glasses (smart glasses-assisted) and post-test without assistance (N = 12).

| | M1: while training with smart glasses | | M2: Unassisted post-test | | Significance (Effect size) |
|---------------------------------------|---------------------------------------|-----------|--------------------------|-----------|--------------------------------------|
| | Median | IQR | Median | IQR | |
| Mean depth (cm) | 4.0 | (2.8–5.0) | 4.2 | (3.2–5.1) | $p = 0.45^*$ |
| Mean rate (CC/min) | 103 | (98–107) | 113 | (107–122) | $p = 0.001^*$ (1.52) [‡] |
| CC with correct release (%) | 24 | (1–79) | 33 | (7–92) | $p = 0.61^†$ |
| CC with correct depth (%) | 0 | (0–54) | 0 | (0–45) | $p = 0.50^†$ |
| CC with correct rate (%) | 66 | (34–87) | 81 | (31–97) | $p = 0.61^†$ |
| CC with correct compression point (%) | 100 | (1–100) | 100 | (18–100) | $p = 0.29^†$ |
| No CC time (in seconds) | 0.5 | (0.0–1.8) | 1.5 | (0.0–2.8) | $p = 0.17^†$ |

AED: Automated External Defibrillator; CC: Chest compressions. IQR: Interquartile range; [†] Wilcoxon's signed ranked test ($p < 0.05$). * Student's t test ($p < 0.05$) and [‡] Cohen's d for Effect Size (in brackets).

Table 3 – Performance times during M1 (smart glasses-assisted test while training) and M2 (unassisted post-test) (N = 12): times and checkpoints (in seconds).

| | M1: while training with smart glasses | | M2: Unassisted post-test | | Significance (Effect Size) |
|---|---------------------------------------|-----------|--------------------------|-----------|--------------------------------------|
| | Median | IQR | Median | IQR | |
| From start to calling 112 | 35 | (21–44) | 25 | (15–63) | $p = 0.78^†$ |
| From calling 112 to CC | 91 | (74–116) | 25 | (9–35) | $p < 0.001^*$ (3.38) [‡] |
| From start to CC | 124 | (106–153) | 61 | (48–78) | $p < 0.001^*$ (2.86) [‡] |
| From start to bringing the AED | 244 | (229–273) | 182 | (169–198) | $p = 0.004^†$ (0.59) [§] |
| From bringing the AED to defibrillation | 95 | (80–103) | 62 | (53–71) | $p < 0.001^*$ (0.47) [‡] |
| From start to defibrillation | 332 | (319–372) | 240 | (233–262) | $p = 0.002^†$ (0.62) [§] |
| From defibrillation to restarting CC | 8 | (6–9) | 8 | (7–9) | $p = 0.78^*$ |
| From start to restarting CC | 340 | (324–381) | 249 | (241–270) | $p = 0.002^†$ (0.62) [§] |

AED: Automated External Defibrillator; CC: Chest compressions; IQR: Interquartile range; [†] Wilcoxon's signed ranked test ($p < 0.05$) and [§] Rosenthal's r for Effect Size (in brackets); * Student's t test ($p < 0.05$) and [‡] Cohen's d test for Effect Size (in brackets).

Table 4 – Perceptual variables during M1 (smart glasses-assisted test while training) and M2 (unassisted post-test) (N = 12) (in a 0–10 scale).

| | M1: while training with smart glasses | | M2: Unassisted post-test | | Significance (Effect Size) |
|--|---------------------------------------|-----------|--------------------------|-----------|--------------------------------------|
| | Median | IQR | Median | IQR | |
| Difficulty of smart glasses use | 2.0 | (1.3–3.0) | 2.0 | (0.3–2.8) | $p = 0.50^†$ |
| Self-perception of performance quality * | 5.5 | (4.3–8.0) | 7.0 | (6.0–7.8) | $p = 0.020^*$ (0.55) [‡] |
| Self-confidence | 7.5 | (5.3–9.0) | 7.0 | (4.0–7.8) | $p = 0.14^*$ |

IQR: Interquartile range; [†] Wilcoxon's signed ranked test ($p < 0.05$); * Student's t test ($p < 0.05$) and [‡] Cohen's test for Effect Size (in brackets).

this reason, we consider essential to evaluate the smart glasses before proceeding to its routine use in training and that is why we set the objective of analyzing the learning process of the BLS after a very brief training in which the participants experienced a sequence of performing with the video assistance of an instructor through smart glasses.

Our main finding was that very brief training using a cardiac arrest simulation in which the participant is video-assisted through smart

glasses is a valid alternative method for learning BLS. There was a good learning in the BLS protocol, the use of the AED, the performance times, and some parameters related to the quality of resuscitation.

This type of training, in which the participant experiences a simulated but quite realistic situation of cardiorespiratory arrest while being video-assisted through the smart glasses, was adequate for to learn the BLS protocol. After the training, practically all the partic-

Participants performed most of the steps of the BLS protocol satisfactory (check breathing, use the AED, start chest compressions...). The steps that fewer participants performed correctly were assessing consciousness and alert that nobody touch the victim before shocking, which only 7 of 12 did correctly. However, this did not imply a deterioration in comparison to M1, so they performed as correctly as they were able to while learning with the smart glasses-assistance of the instructor.

In the event of a real cardiac arrest, a good performance following the BLS protocol would favor a good ABC approach, the call to emergency medical services, the initiation of resuscitation, and the use of the AED. All this is integrated into the so-called chain of survival in which the performance of the witness is key,¹⁷⁻¹⁹ and if done properly, as the participants in this study learned, it can ensure more chances of survival.¹⁹ All except one participant in this study learned to use the AED without errors (one of them did not use it when asked to act autonomously). Also, when they acted without the help of the dispatcher, all AED defibrillations were completed within 5 minutes (mean: 4 minutes). Note that, in our simulation scenario, the AED arrived after 2 minutes of resuscitation and it took about 1 minute from the AED arrival until the shock was delivered. It is a quick action that in a real situation would be very important for survival.¹⁹⁻²¹ In our study, when participants performed autonomously, they started chest compressions quickly (mean: 62 seconds from the beginning, and after the ABC approach and the call to emergency medical services). In a real situation of out-of-hospital cardiorespiratory arrest, this immediate initiation of CPR would be positive because it could double or triple the survival rate from cardiac arrest.^{2,22} It is remarkable that performing times even doubled in the smart glasses-assisted test (M1) compared to the unassisted post-test (M2). This was to be expected because in M1, the variables were assessed while they were training in communication with the instructor through the smart glasses. During the training, the participants took longer to perform because they were learning to act by listening to the trainer's instructions and corrections. Otherwise, in the unassisted post-test (M2), the participants limited themselves to performing autonomously.

In addition to early resuscitation, CPR must be performed with quality. In our study, very brief training with smart glasses was useful for learning the proper compression point (100% of the chest compressions with hands positioned correctly), minimizing interruptions (they only stopped for an average of 1.5 seconds in the 2 minutes of chest compressions), and having a guideline conform compression rate within 100 and 120 chest compressions/min (which was 113 chest compressions/min). However, this training was not adequate to achieve a good chest compressions depth. Performing chest compressions too shallow is a recurring mistake in laypeople, and due to that some previous studies with self-learning BLS achieve good compression depth between 5 and 6 cm and others no,²³⁻²⁴ the factors contributing to these differences need to be explored in the future. In our study, the visual information that the instructor had was through the smart glasses' front camera (subjective vertical vision of the participant). This angle of vision is not optimal to be able to correct just-in-time the depth of the chest compressions, so the instructor should have been encouraged to insist on the "push hard" correction. An improvement proposal for our educational methodology would be the incorporation of a double feedback system integrated into the smart glasses, in which both the instructor and student might see the real depth of each chest compression in real-time. It would be expected that this combination of technologies

would favor the learning of a better quality of resuscitation with a better chest compressions depth.

This type of educational training has been adequate for learning BLS, with the exception of the recently named resuscitation quality parameters. The novelty of this type of CPR training lies in the use of the video call with smart glasses as a communication wearable. The instructor can carry out personalized training encouraging the learner to continue acting when he/she does it well or correcting him/her based on what he/she sees and hears through the smart glasses. This type of training through the use of wearable technology and augmented reality with smart glasses may engage many learners⁴ and it can be especially interesting to apply in remote places, such as rural areas, where it is more difficult to implement face-to-face BLS educational programs.⁹

A possible barrier to this type of tele-training could have been the use of the wearable itself. However, the participants stated that the smart glasses are very easy to use (ease of use: 2 out of 10, they had enough with less than 5 minutes to become familiar with them) and generated good self-confidence and self-perception of performance quality (7 over 10).

Based on the findings of this study, the option of teaching BLS with this new educational methodology which is characterized by being very brief (<7 minutes) and the use of telematics through augmented reality with smart glasses opens up. Experiencing a simulated cardiorespiratory arrest execution with the video assistance of the instructor with the smart glasses has made the laypeople participants quite competent to perform autonomously. It would be expected that, after this learning, if the participants witness a real cardiorespiratory arrest, they may have greater guarantees of helping the victim.

For the implementation of this type of training, it would be necessary to take into account the costs of the technology itself and the number of instructors. The 2021 cost of these smart glasses was around 1,200 euros and it is necessary to connect them to the Internet. Furthermore, there has to be an instructor for each student. The positive aspect is that the instructor can individualize the corrections of each student based on what he/she sees and hears in the video call through the smart glasses.

Apart from the future limitations in the implementation of this learning methodology, this study has had certain limitations in itself. It must be taken into account that this is a pilot study with a small sample size, a larger number of participants could favor a better statistical power and more significant differences. When interpreting the results, the profile of the participants must be considered. They were laypeople with no prior knowledge of BLS, so we value as very positive the fact that with such a short training, they learned substantially. In addition, they were all students from a university degree in sports, so one can assume that they had a certain ability for learning simple procedures such as BLS, and motor skills such as chest compressions.²⁵

In the future, it could be interesting to explore whether short training programs and the use of new communication technologies, such as smart glasses, could be a good alternative method of learning BLS for laypeople in studies with a higher statistical power.

Conclusions

Our pilot study suggest that smart glasses-assisted training can facilitate teaching basic life support to laypeople. Our very brief training

experiencing a simulation of video-assisted cardiac arrest care with smart glasses has demonstrated promising results as an educational method for learning the basic life support protocol, the use of the automated external defibrillator, and some skills to perform basic life support. This technology can be easily used and seems useful for remotely learning how to respond to cardiorespiratory arrest, but additional studies are still needed to ascertain its impact at educational level. This method has potential for smart glasses assisted training to increase access to basic life support education, especially in remote or underserved areas. Future research should explore the potential synergies between smart glasses and cardiopulmonary resuscitation quality feedback systems.

Conflicts of Interest

None.

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6.3.3 Article 06 – Title: New communication tool for basic life support training: smart glasses. A quasi-experimental study



Figure 6-6. Screenshot of article 06 identification.

Available at <https://www.sciencedirect.com/science/article/pii/S0210569123002516>

6.3.3.1 Article abstract

Aim: To analyze the effectiveness of a teaching-learning methodology for teletraining in basic life support (BLS) based on communication through smart glasses. **Design:** Pilot quasi-experimental non-inferiority study. **Participants:** Sixty college students. **Interventions:** Randomization of the participants in: tele-training through smart glasses (SG) and traditional training (C) groups. Both training sessions were very brief (less than 8 minutes) and included the same BLS content. In SG, the instructor trained through a video call with smart glasses. **Main variables of interest:** The BLS protocol, the use of AED, the quality of resuscitation and the response times were evaluated. **Results:** In most of the BLS protocol variables, the resuscitation quality and performance times, there were no statistically significant differences between groups. There were significant differences (in favor of the SG) in the assessment of breathing (SG: 100%, CG: 81%; $p = 0.013$), the not-to-touch warning before applying the shock (SG: 79%, CG: 52%; $p = 0.025$) and compressions with correct recoil (SG: 85%, CG: 32%; $p = 0.008$). **Conclusions:** Laypeople BLS-AED brief tele-training through smart glasses could potentially be, at least, as effective as traditional training methods. In addition, smart glasses could be more advantageous than traditional teaching for certain points of the BLS protocol and chest compressions quality, probably due to the capability of real-time visualization of images which supports the BLS sequence. Augmented reality supported teaching should be considered

for BLS training, although caution is required in extrapolating findings, and further in-depth studies are needed to confirm its potential role depending on concrete target populations and environments.

6.3.3.2 Evidence of Quality

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ORIGINAL ARTICLE

New communication tool for basic life support training: smart glasses. A quasi-experimental study

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KEYWORDS

Smart glasses;
Out-of-hospital
cardiac arrest;
Bystander;
Cardiopulmonary
resuscitation;
Basic life support

Abstract

Aim: To analyze the effectiveness of a teaching-learning methodology for teletraining in basic life support (BLS) based on communication through smart glasses.

Design: Pilot quasi-experimental non-inferiority study.

Participants: Sixty college students.

Interventions: Randomization of the participants in: tele-training through smart glasses (SG) and traditional training (C) groups. Both training sessions were very brief (less than 8 min) and included the same BLS content. In SG, the instructor trained through a video call with smart glasses.

Main variables of interest: The BLS protocol, the use of AED, the quality of resuscitation and the response times were evaluated.

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S. Aranda-García, M. Otero-Agra, C. Berlanga-Macias et al.

Results: In most of the BLS protocol variables, the resuscitation quality and performance times, there were no statistically significant differences between groups. There were significant differences (in favor of the SG) in the assessment of breathing (SG: 100%, C: 81%; $p = 0.013$), the not-to-touch warning before applying the shock (SG: 79%, C: 52%; $p = 0.025$) and compressions with correct recoil (SG: 85%, C: 32%; $p = 0.008$).

Conclusions: Laypeople BLS-AED brief tele-training through smart glasses could potentially be, at least, as effective as traditional training methods. In addition, smart glasses could be more advantageous than traditional teaching for certain points of the BLS protocol and chest compressions quality, probably due to the capability of real-time visualization of images which supports the BLS sequence. Augmented reality supported teaching should be considered for BLS training, although caution is required in extrapolating findings, and further in-depth studies are needed to confirm its potential role depending on concrete target populations and environments.

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PALABRAS CLAVE

Smart glasses;
Parada
cardiorrespiratoria
extrahospitalaria;
Testigo;
Reanimación
cardiopulmonary;
Soporte vital básico

Nueva herramienta de comunicación para el entrenamiento de soporte vital básico: smart glasses. Un diseño cuasiexperimental**Resumen**

Objetivo: Analizar la efectividad de una metodología de enseñanza-aprendizaje de teleformación en soporte vital básico (SVB) basada en la comunicación a través de smart glasses.

Diseño: Estudio piloto cuasi experimental de no inferioridad.

Participantes: Sesenta estudiantes universitarios.

Intervenciones: Aleatorización de los participantes en: grupo de teleformación a través de smart glasses (SG) y formación tradicional (C). Ambas sesiones de entrenamiento fueron muy breves (<8 minutos) e incluyeron el mismo contenido en de SVB. En SG, el entrenamiento fue comunicándose a través de una videollamada con smart glasses.

Variables de interés principales: Se evaluó el protocolo del SVB, el uso de DEA, la calidad de la reanimación y los tiempos de actuación.

Resultados: En la mayoría de las variables del protocolo del SVB, la calidad de la reanimación y los tiempos de ejecución, no hubo diferencias estadísticamente significativas entre grupos. Hubo mejor actuación de SG al valorar la respiración (SG: 100%, C: 81%; $p = 0,013$), el avisar antes de la descarga del DEA (SG: 79%, C: 52%; $p = 0,025$) y las compresiones con buena reexpansión (SG: 85%, C: 32%; $p = 0,008$).

Conclusiones: El tele-entrenamiento en SVB-DEA para legos con smart glasses podría llegar a ser, al menos, tan efectivo como un método tradicional de enseñanza. Además, las smart glasses podrían ser más ventajosas para ciertos aspectos del protocolo del SVB y la calidad de las compresiones, probablemente debido a la capacidad de visualización de imágenes en tiempo real. La enseñanza basada en la realidad aumentada debe considerarse para la capacitación en SVB, aunque se requiere tanto cautela en la extrapolación de hallazgos como estudios futuros con mayor profundidad.

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Introduction

The European Resuscitation Council (ERC) recommends the teaching of basic life support (BLS) so that any person may act correctly when witnessing out-of-hospital cardiac arrest (OHCA).¹ The protocol includes knowing how to recognize OHCA, how to use an automated external defibrillator (AED), and how to perform high-quality cardiopulmonary resuscitation (CPR).² Given the relationship between the quality of CPR and recovery from OHCA,³ several BLS educational programs for laypeople have been proposed – all with different characteristics in terms of duration, frequency, contextualization and the use of communication technologies. The

traditional BLS education protocols are face-to-face programs with a long duration and are spaced over time, though they have evolved towards more brief and continuous protocols of demonstrated efficacy.⁴⁻⁶ There are even very short programs lasting under 10 min, that have been shown to be useful.⁷

Developments in communication technology have also made it possible to teach BLS on a remote basis. Telematic training programs through smartphones could afford results comparable to those obtained with face-to-face protocols, with the added advantage of having better material and human resources, and of being accessible to almost anyone.⁸ In relation to communication technologies, smart glasses

have been proposed as a new teletraining tool.^{9–13} A recent pilot study involving this communication technology found teleassistance with augmented reality based on the use of smart glasses to be useful in teaching BLS and the use of an AED.¹³ However, optimum results in terms of resuscitation quality were not obtained, possibly due to the short training time involved. The authors underscored the potential of this wearable, and considered that further studies are needed to compare its efficacy against more traditional training programs.¹³

Accordingly, the present study was carried out to analyze the effectiveness of a teaching-learning methodology for teletraining in BLS involving communication through smart glasses, and to compare it with a traditional face-to-face training program.

Patients and methods

A quasi-experimental non-inferiority pilot study was carried out, involving a total of 60 health sciences and nursing university students of the University of Vigo (Pontevedra, Spain). The participants were required to have had no training in BLS during the previous two years, and no physical problems preventing them from performing chest compressions (CC). The convenience sample was randomized to a teletraining intervention group with smart glasses (SG) and a traditional face-to-face training control group (C) (Fig. 1). The study protocol was approved by the Ethics Committee for Clinical Research of the Catalan Sports Council (reference number 026/CEICGC/2022), and all the participants signed the corresponding informed consent before randomization.

The participants underwent a brief 6–8 min individual training session imparted by an ERC-certified instructor. Use was made of a Resusci Anne Q CPR simulator (Laerdal, Norway) and a training AED (AED Trainer 2, Laerdal, Norway). The training of both groups followed the same sequence, distributed into four blocks: (i) ABC assessment: safety at the scene, check of consciousness, opening of the airway and check of breathing; (ii) alert the emergency medical services (dial 112), set up the AED and follow instructions for use; (iii) perform continuous quality CC: adequate compression point, rhythm with metronome, depth and compression-decompression ratio; and (iv) complete intervention protocol. In the first three blocks, the instructor provided an explanation/demonstration of each of the techniques, and the student then reproduced them with the necessary corrections from the instructor. In the fourth block, the student carried out the complete intervention protocol as learned, with corrections from the instructor as needed.

With regard to the teaching methodology, each group was instructed differently. The teletraining intervention group received a brief training session through the smart glasses (Vuzix Blade AR, Vuzix, USA) linked to the instructor via wifi 4 G with the App Vuzix Remote Assist (Vuzix, USA),^{11–13} located at a control post some distance from the training/evaluation area. The SG instructor explained the techniques verbally, sending supporting animated images that the participant could see with the smart glasses¹¹: opening of the airway, evaluation of breathing, compression point and position for performing CC (in frontal and

lateral view). The corrections were made from the control post based on what the instructor was hearing and seeing through the smart glasses in the subjective viewing of the participant.

On the other hand, the C underwent a brief traditional face-to-face training session with the instructor in the same physical space as the participant, explaining and showing the techniques, and correcting the student as needed.

Immediately after the training session, the performance of each individual participant in response to a simulated cardiac arrest was evaluated. Placing the situation in context, the participants were instructed to imagine a person fainting in their presence, and to respond as if the situation were real, using what they had just learned (see supplementary video).

The study variables were evaluated in three main blocks: (a) application of the BLS protocol and use of the AED, assessed with a dichotomic checklist (Yes = correctly performed, and No = not performed or incorrectly performed); (b) quality of CC assessed after discharge of the AED and during two consecutive minutes with the simulator connected to the App Q CPR training (Laerdal, Norway); and (c) response times (Fig. 2).

The data were reported as measures of central tendency (median [Me]) and dispersion (interquartile range [IQR]) in the case of continuous variables, and as absolute and relative frequencies in the case of categorical variables. Data homogeneity was assessed with plot techniques and the Shapiro–Wilk test. The comparison of means of variables exhibiting a normal distribution was carried out using the Student t-test, while the Mann–Whitney U-test was used in the absence of normal data distribution. In those comparisons showing statistically significant differences, the effect size (ES) was calculated with the Rosenthal test, classified as follows: insignificant (<0.2), small (0.2–0.5), moderate (0.5–0.8), important (0.8–1.3) and very important (>1.3). Categorical variables in turn were compared with the chi-square test, calculating the ES with Cramer's V-test, and classified as follows: insignificant (<0.1), small (0.1–0.3), medium (0.3–0.5) and large (>0.5). Statistical significance was considered for $p < 0.05$. The SPSS version 20.0 statistical package (IBM Corp., Armonk, NY, USA) was used throughout.

Results

The study included 60 participants (75% women: 86% women in SG and 65% in C; $p = 0.053$), with a median age of 20 years (range 18–22), a height of 1.65 m (range 1.6–1.7), and a weight of 63 kg (range 56–69) kg.

Following training, most of the participants in both groups correctly performed the different steps of the BLS protocol as established by the recommendations of the ERC (Table 1).² No significant differences were observed between SG and C in relation to the different variables, with the exception of the assessment of breathing (SG: 100%, C: 81%; $p = 0.013$) and the warning not to touch the victim before AED discharge (SG: 79%, C: 52%; $p = 0.025$).

With regard to the quality of CC, there were no statistically significant differences between the groups, with the exception of the percentage of compressions with correct recoil (SG: 85%, C: 32%; $p = 0.008$) (Table 2). In both

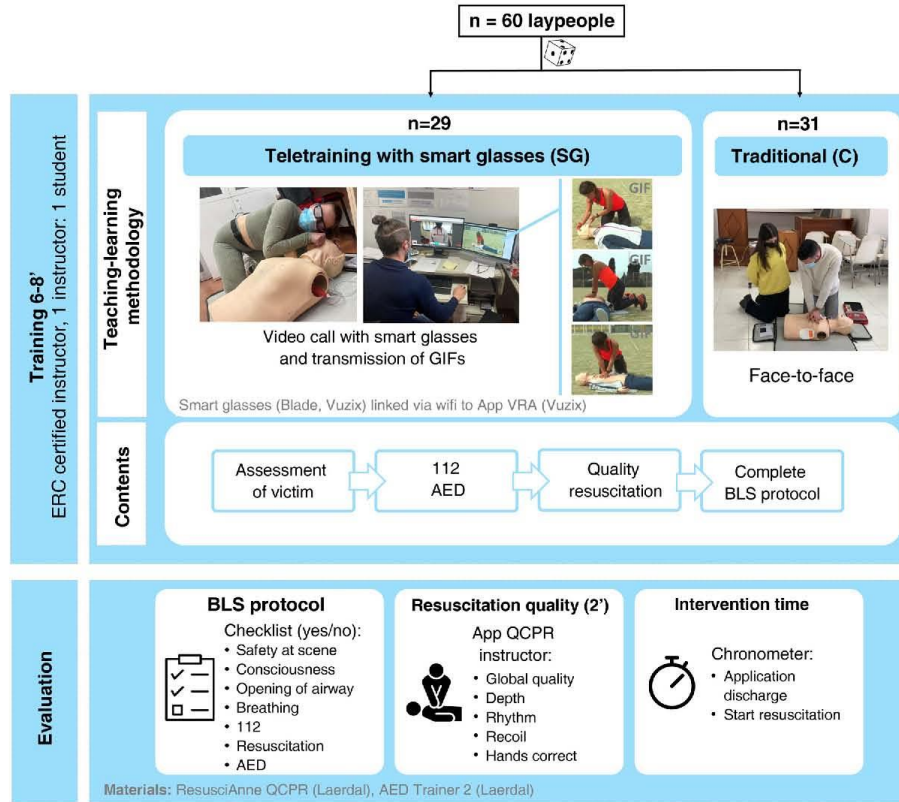


Figure 1 Schematic representation of the study design and procedures.

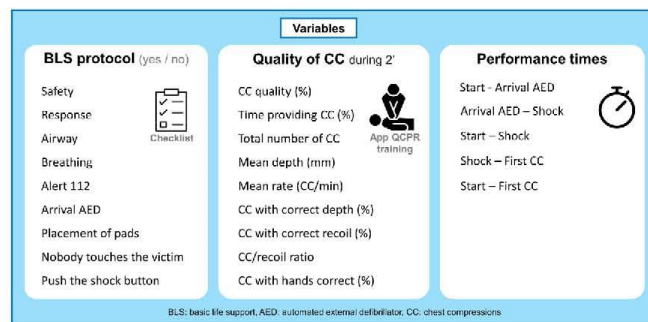


Figure 2 Study variables: basic life support sequence, quality of the chest compressions and response times.

groups the quality of CC did not reach 70%, the mean depth was slightly under 50 mm, and the rhythm was equal to or slightly above 120 compressions/minute, with no significant differences between the groups (Table 2).

The time from the start of the intervention to the arrival of the AED was short and significantly longer (8 s more) in SG than in C (SG: 38 s, C: 30 s; $p = 0.041$). However, there were no statistically significant differences between the groups

Table 1 Basic life support sequence by groups.

| | Smart glasses (N = 29) | | Control (N = 31) | | P-value |
|---------------------------------|------------------------|---------|------------------|---------|------------------------------------|
| | N | (%) | N | (%) | |
| Safety | 13 | (45 %) | 20 | (65 %) | p = 0.13 ^a |
| Level of consciousness | 24 | (83 %) | 20 | (65 %) | p = 0.11 ^a |
| Airway | 29 | (100 %) | 30 | (97 %) | p = 0.33 ^a |
| Breathing | 29 | (100 %) | 25 | (81 %) | p = 0.013 ^a (ES = 0.32) |
| Alert emergency medical service | 28 | (97 %) | 29 | (94 %) | p = 0.59 ^a |
| About AED | 29 | (100 %) | 31 | (100 %) | - |
| Placing of electrodes | 25 | (86 %) | 26 | (84 %) | p = 0.80 ^a |
| Check nobody touches the victim | 23 | (79 %) | 16 | (52 %) | p = 0.025 ^a (ES = 0.29) |
| Apply discharge | 29 | (100 %) | 31 | (100 %) | - |

AED, Automated external defibrillator; N, Absolute frequency; ES, effect size. (%), Relative frequency.

^aChi-square test (p = 0.05).

Table 2 Quality of cardiopulmonary resuscitation (CPR) by groups.

| | Smart glasses (N = 29) | | Control (N = 31) | | P-value |
|---------------------------------------|------------------------|-------------|------------------|-------------|------------------------------------|
| | Me | IQR | Me | IQR | |
| Quality of CC (%) | 49 | (11–76) | 66 | (34–84) | p = 0.10 ^a |
| Time performing CC (%) | 100 | (100–100) | 100 | (100–100) | p = 0.18 ^a |
| Total number of CC | 249 | (223–263) | 237 | (219–250) | p = 0.25 ^b |
| Mean depth (mm) | 43 | (34–54) | 48 | (39–58) | p = 0.06 ^b |
| Mean rhythm (CC/min) | 126 | (112–132) | 120 | (110–128) | p = 0.32 ^b |
| CC with adequate depth (%) | 16 | (0–61) | 30 | (1–53) | p = 0.44 ^a |
| CC with adequate recoil (%) | 85 | (37–100) | 32 | (6–85) | p = 0.008 ^a (ES = 0.34) |
| CC/decompression ratio | 1.00 | (0.77–1.18) | 0.92 | (0.79–1.04) | p = 0.29 ^a |
| CC with correct position of hands (%) | 100 | (100–100) | 100 | (100–100) | p = 0.07 ^a |

CC: Chest compressions. Me: Median. IQR: Interquartile range (Q1 - Q3). ES: Effect size.

^aMann-Whitney U-test (p = 0.05).

^bStudent t-test for independent samples (p = 0.05).

Table 3 Response times by groups.

| | Smart glasses (N = 29) | | Control (N = 31) | | P-value |
|------------------------------------|------------------------|----------|------------------|----------|------------------------------------|
| | Me | IR | Me | IR | |
| From start to setup of AED (s) | 38 | (30–47) | 30 | (21–46) | p = 0.041 ^a (ES = 0.26) |
| From setup of AED to discharge (s) | 65 | (56–71) | 67 | (58–75) | p = 0.36 ^a |
| From start to discharge (s) | 102 | (86–119) | 96 | (80–116) | p = 0.38 ^a |
| From discharge to start of CC (s) | 10 | (8–13) | 10 | (8–11) | p = 0.69 ^b |
| From start to first CC (s) | 116 | (99–127) | 102 | (88–125) | p = 0.29 ^a |

AED, Automated external defibrillator; CC, chest compressions; Me, Median; IQR, Interquartile range. (Q1–Q3). S = Seconds. ES: Effect size.

^aMann-Whitney U-test (p = 0.05).

^bStudent t-test for independent samples (p = 0.05).

in terms of the time to application of the discharge or the start of CC (Table 3).

Discussion

To our knowledge, this is the first quasi-experimental study on the efficacy of a BLS-AED teletraining protocol with smart glasses targeted to first-aid laypeople. The results obtained

indicate that this kind of training is as effective as traditional face-to-face training in terms of most of the variables related to the BLS protocol, the quality of CC, and the response times. Furthermore, training with smart glasses is comparatively superior in some aspects related to the quality of the intervention, particularly the ABC assessment approach (evaluation of breathing), use of the AED (warning not to touch the victim) and the quality of CC (recoil).

Regarding the specific results of the BLS sequence and quality of CC, the two groups showed strong compliance with the recommendations of the ERC.² Both short training methods were useful in teaching the BLS protocol to laypeople. All of the participants showed very good performance in certain parameters related to the quality of resuscitation (e.g., correct placement of the hands during CC, avoiding interruptions, and with good CC rhythm). However, in our study, the quality of C_T was sub-optimal, mainly because CC was too superficial (between 40 and 50 mm instead of the desired 50–60 mm).² As in previous studies,^{8,14,15} this caused the global quality of resuscitation (chest compressions) to be acceptable, but below the established arbitrary minimum criterion.¹⁶ Thus, while both methods were useful for learning the BLS protocol, they were not optimum in securing high-quality CC. Nevertheless, it was not our intention to achieve maximum resuscitation quality but rather to compare two teaching methods involving the same dedication time, and we chose this particular format because there are numerous examples of brief training protocols.¹⁷ Brief training strategies have advantages and disadvantages that fall beyond the scope of this study. In very short protocols of this kind, where the students have very little time to train, it is common to not always reach optimum resuscitation quality.⁷ In this regard, the ERC recommends frequent repetitive trainings, spaced and divided into short cycles, in order to maintain competence in resuscitation.^{1,6}

Recently, new technological tools such as virtual or augmented reality have been proposed for the training of laypeople.¹ In this regard, augmented reality training with smart glasses could prove adequate for “very brief” tele-training protocols, because the results obtained are similar to those of face-to-face training strategies.

To date, no experimental or quasi-experimental studies have analyzed the efficacy of smart glasses in laypeople versus face-to-face training; nevertheless, some studies have demonstrated their applicability in the training of healthcare professionals in clinical contexts¹⁸ or in laypeople, but with the lack of a control group.¹³ In healthcare professionals, the applicability of smart glasses in simulated neonatal resuscitation training,¹⁹ and resuscitation quality in in-hospital pediatric cardiac arrest, have been studied.²⁰ In laypeople, Aranda-García et al., following training based on the experience of cardiac arrest video-assisted with smart glasses (the same communication system as that used in our study), reported that the participants were able to perform a good BLS protocol, with good handling of the AED.¹³

In the present study, the participants in SG performed significantly better than those in C in three aspects: evaluation of breathing, making sure nobody touches the victim at discharge, and CC recoil. The evaluation of breathing is crucial for determining whether the victim is under cardiac arrest and requires CC and AED.² Ensuring safety at the scene before discharge is important for the rescuer and for the efficacy of discharge.^{21,22} In turn, the improved CC recoil recorded in SG (53% more CC with good recoil than in C) is decisive at the clinical level, since it reflects the CC in which full chest recoil occurs, and thus adequate cardiac output is maintained. In this respect, the fact that the participants in C were significantly taller could have influenced the poorer results in terms of recoil.²³

Intervention in the case of OHCA must be made as quickly as possible, since survival and morbidity in this type of emergency are time-dependent.²⁴ In this regard, augmented reality could be considered useful given the quickness of resuscitation, since the time to AED discharge and the start of CC was less than two minutes from the start of the scene (in both groups).²⁴ The controls (C) were 8 s faster in terms of arrival of the AED, though this difference was considered to be clinically negligible, since it did not influence the time to discharge.

As both interventions were similar regarding training time, content and the individualization of corrections (proportion 1 instructor: 1 student), the possible reasons for the differences in favor of SG are not fully clear. However, the explanation could be related to the real-time visioning of animated images in SG. Although the purpose of transmitting these images to the smart glasses was to show the participant the BLS skills (e.g., the opening of the airway, evaluation of breathing), it may have caused the student to pay special attention to these techniques and therefore to make a greater effort to perform them very well. In any case, it is considered to be very positive that remote training guided by smart glasses yields results that are not inferior to and may even be better than those obtained with the gold standard (individualized face-to-face training).

In coincidence with our findings, other studies have also evaluated the impact upon resuscitation quality of other learning methods based on new technologies, such as virtual reality and augmented reality. In the same way, as with smart glasses, these alternatives compared with the traditional protocols offer the opportunity of a new effective and very realistic method – though further studies are needed to be able to establish solid recommendations.^{25–27} In any case, given its broad applicability and the lesser need to mobilize human and material resources, interventions based on smart glasses could become a protocolized very brief BLS training tool. In terms of practical applicability, this type of training could be particularly interesting in remote or rural settings with good internet connectivity but with limited access to resuscitation training due to instructor travel costs or the site where teaching is to take place.²⁸ However, securing all the contemplated resources might not be feasible in certain scenarios; further studies in this line therefore could afford data on which to base future political and sociosanitary interventions in this field. As an example, approximately 18% of the Scottish population and 16% of the Spanish population live in remote or rural areas^{29,30} where emergency services take longer in arriving on site, and where a greater proportion of trained bystanders could improve the survival rates.⁸ This type of training involving the use of smart glasses as a remote method outside the classroom could allow individualized training adapted to the needs of each student, in line with the proposal of the ERC.³ Likewise, this study could constitute a starting point for the long-term development of educational programs with repeated and periodic updates. In this sense, it would be advisable for future studies to address the retaining of knowledge and skills over the middle and long term (3, 6 and more months), in order to assess consolidation of the learning gained with this type of training.

The present study has limitations that make it necessary to interpret the findings with caution: (i) the sample size and

target population involved could limit the extrapolation of the results to the general population and the identification of differences between groups. Although the participants in our study were laypeople in terms of knowledge and skills in BLS-AED, their previous knowledge in truncl disciplines such as anatomy and/or pathophysiology could bias the results obtained; (ii) although wifi allowed the study to be carried out under optimum conditions, real-life circumstances could pose limitations in the application of this technology due to online connectivity issues; (iii) the autonomy of smart glasses is limited, though continuous advances in research evidencing the benefits of these devices may favor their development and compensate this limitation; (iv) although the global quality of resuscitation in SG was not inferior to that observed in C, based on training with previously validated methodologies, the quality of the chest compressions in both groups fell short of the current recommendations. Nevertheless, the observed non-inferiority of SG allows us to view video communication with smart glasses as a potentially useful tool for training in BLS-AED, and could open future lines of research in this field – including analyses of the barriers preventing the recommended quality levels from being met. Thus, further studies on communication with smart glasses are needed, involving population samples from different contexts, with middle and long-term evaluation of the retaining of learning. Likewise, assessment is required of the efficacy of individualized training sessions that might not be so short but which are imparted periodically in the context of the “brief rolling refresher” concept^{31,32} involving augmented reality settings.

In conclusion, brief BLS-AED teletraining with smart glasses for laypeople could become at least as effective as the traditional training methods. Furthermore, smart glasses could be more advantageous than traditional training in relation to certain aspects of the BLS protocol and the quality of chest compressions, probably due to the capacity for real-time visualization of images supporting the BLS sequence. Teaching based on augmented reality should be considered for training in BLS, though caution is required in extrapolating the findings, and future studies are needed to evaluate new theoretical and practical teaching methods allowing laypeople or healthcare professionals to acquire and retain adequate quality in performing chest compressions. Hence, with due caution, the potential of such technology should be explored in different settings and target populations, with methodological differences in terms of the established training and refresher or retraining times.

Authors' contribution

SAG and RBF designed the study. SAG and RBF were the principal investigators. ARN and FFM established the methodology. SAG, RBF, and ARN coordinated the study. SAG, CBM, RBF, MOA, JD, ASV, and FFM conducted the data collection for the study. MOA and JD performed the data information dump and statistical analysis. SAG wrote the manuscript with the support of CBM and ARN. Finally, all authors read, revised, and approved the manuscript.

Conflict of interest

No conflict of interest to declare.

Funding

No financing to declare.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.medin.2023.09.002>.

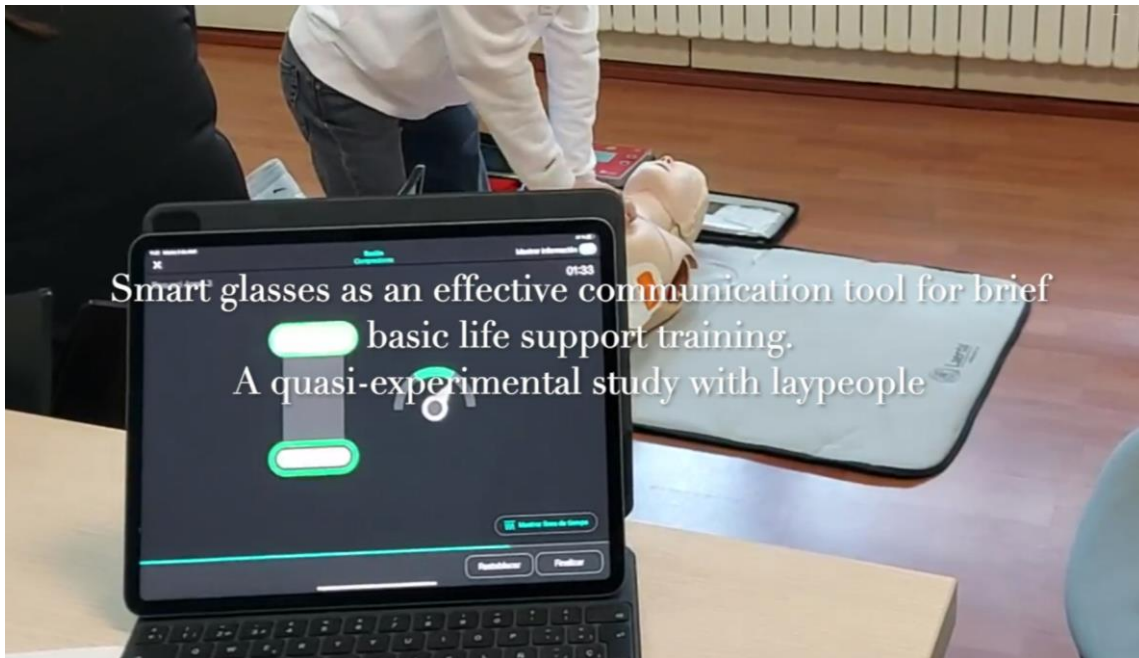
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Supplementary materials:

The following supplementary video can be downloaded at:
<http://dx.doi.org/10.1016/j.medin.2023.09.002> or
<https://x.com/silviaaranda46/status/1721452240387379692?s=20>



6.4 DISSEMINATION OF RESULTS AND SCIENTIFIC OUTREACH AWARDS

In addition to the dissemination conducted in indexed and specialized scientific journals, results have been disseminated to both the specialized population and the general public through presentations in congresses or international scientific conference (as an invited speaker or as free presentations), social media and press.

The presentations related to the thesis at congresses or international scientific conferences are listed below in chronological order:

1. **Communication in congress.** Aranda-García S, Otero-Agra M, Berlanga-Macías C, Fernández-Méndez F, Barcala-Furelos R, Domingo J, et al. Basic life support training with augmented reality with smart glasses vs. traditional face-to-face education. A quasi-experimental pilot study. In: European Resuscitation Council Congress - Resuscitation 2023 - Barcelona nov 2-4.
2. **Communication in congress.** Aranda-García S, Barrio-Cortes J, Fernández-Méndez F, Otero-Agra M, Darné M, Herrera-Pedroviejo E, et al. Is teleassistance with smart glasses better than by telephone? A randomized comparative study with laypeople on basic life support. In: European Resuscitation Council Congress - Resuscitation 2023 - Barcelona nov 2-4.
3. **Communication in congress.** **Aranda-García S**, Barcala-Furelos R, Martínez-Isasi S, Otero-Agra M, Darné M, Rodríguez-Nuñez A. Soporte vital básico y desfibrilador videoasistido con smart glasses vs. asistido telefónicamente. Estudio piloto experimental. XXXIII Congreso Nacional SEMES Madrid 2023. Madrid; 2023. <https://www.semes.org/wp-content/uploads/2023/06/LibroComun-SEMES2023.pdf>
4. **Invited to round table of international webinar.** Aranda-García S. Smartglasses and augmented reality for CPR. In: European Resuscitation Council: Experiences with virtual reality for CPR training. Webinar; 2022. <https://www.youtube.com/watch?v=Mr1VhIPt4mQ> (Figure 6-7).
5. **Communication in congress.** Darné M, Aranda-García S, Fernández-Méndez F, Herrera-Pedroviejo E, Barcala-Furelos R, Barrio-Cortes J, et al. Teleasistencia con smart glasses para la actuación del lego en soporte vital básico. Comparativa con la asistencia telefónica tradicional del operador de emergencias. Congreso Internacional de Bandera Azul: sostenibilidad, salud y seguridad. Las Palmas de Gran Canaria, España: 2022.
6. **Communication in congress.** Aranda-García S, Berlanga-Macías C, Barcala-Furelos R, Otero-Agra M, Cosido-Cobos Ó, Rodríguez-Nuñez A, et al. Formación en soporte vital básico mediante gafas inteligentes en legos. Un estudio experimental. Congreso Internacional de Bandera Azul: sostenibilidad, salud y seguridad. Las Palmas de Gran Canaria, España: 2022.
7. **Communication in congress.** Aranda-García S, Fernández-Méndez F, Santos-Folgar M, Pardo-Ríos M, Hernández-Sánchez E, Barcala-Furelos R. Smart glasses para la asistencia remota a un socorrista en un parto en la playa. In: ISBN: 978-84-09-41191-7, editor. XXXII Congreso Nacional SEMES VIGO 2022. Vigo; 2022. https://www.semes2022.org/uploads/docs/Libro_comunicaciones_SEMES2022.pdf

8. **Communication in congress.** Barcala-Furelos R, Aranda-García S, Otero-Agra M, Fernández-Méndez F, Martínez-Isasi S, Rodríguez-Núñez A. Reanimación guiada por smart glasses a bordo de un barco de pesca. Evaluación tecnológica en la asistencia. In: XXXII Congreso Nacional SEMES VIGO 2022. Vigo: ISBN: 978-84-09-41191-7; 2022. https://www.semes2022.org/uploads/docs/Libro_comunicaciones_SEMES2022.pdf
9. **Communication in congress.** Aranda-García S, Fernández-Méndez F, Santos-Folgar M, Pardo-Ríos M, Hernández-Sánchez E, Barcala-Furelos R. Smart glasses para la asistencia remota a socorristas en un parto en la playa. In: XXXII Congreso Nacional SEMES VIGO 2022. Vigo: 978-84-09-41191-7; 2022. https://www.semes2022.org/uploads/docs/Libro_comunicaciones_SEMES2022.pdf
10. **Guest speaker at congress.** Aranda-García S, Santos-Folgar M, Fernández-Méndez F, Barcala-Furelos R, Pardo-Ríos M, Rodríguez-Núñez A. Telemedicina de urgencias. La asistencia al parto mediante Smart Glasses. In: I Jornadas Internaciones de eHealth, educación e inclusión. Oviedo: ISBN: 978-84-09-44305-5; 2022.
11. **Guest speaker at congress.** Barcala-Furelos R, Carracedo-Rodríguez E, Aranda-García S. Asistencia guiada por Smart-Glasses a personas legas. Los bateiros gallegos. In: I Jornadas Internaciones de eHealth, educación e inclusión. Oviedo: ISBN: 978-84-09-44305-5; 2022.
12. **Guest speaker at congress.** Aranda-García S, Barcala-Furelos R, Berlanga-Macías C, Otero-Agra M, Cosido-Cobos Ó, Rodríguez-Núñez A, et al. Teleformación con Smart-glasses en Soporte Vital Básico. In: I Jornadas Internacionales de eHealth, educación e inclusión. ISBN: 978-84-09-44305-5; 2022.
13. **Communication in congress.** Barcala-Furelos R, Aranda-García S, Fernández-Méndez F, Otero-Agra M, Alonso-Calvete A, Rodríguez-Núñez A. Video asistencia con smartglasses durante navegación de soporte vital básico y desfibrilación semiautomática. In: Annual Meeting of the Society for Simulation in Europe. Sevilla, España; 2022.

Guest speaker ERC webinar

WEBINAR

Experiences with virtual reality for CPR training

FRIDAY OCTOBER 21 • 06 pm CET

MODERATORS
Tommaso Scquizzato (Italy), Federico Semeraro (Italy)

SPEAKERS

Interactive CPR training
Martin Percy (UK)

Smartglasses and augmented reality for CPR
Silvia Aranda-García (Spain)

VR for Kids Save Lives
Federico Semeraro (Italy)

VR and CPR training: what's the evidence?
Mackinnon Ralph (UK)

Register for free via CoSy – 'Congress/webinar registration' or via the ERC website under 'Events'

EUROPEAN RESUSCITATION COUNCIL

YouTube <https://www.youtube.com/watch?v=IAWT5BUGSJU>

Figure 6-7. Guest speaker European Resuscitation Council (ERC) webinar.
Available at <https://www.youtube.com/watch?v=IAWT5BUGSJU> (Author-created figure)

The results were disseminated both to professionals in the field of out-of-hospital emergency care and to the general public. This dissemination was carried out through social media posts and press releases, as well as through relevant research groups and scientific societies. Additionally, the personal accounts of the research team were utilized for this purpose (Figure 6-8).

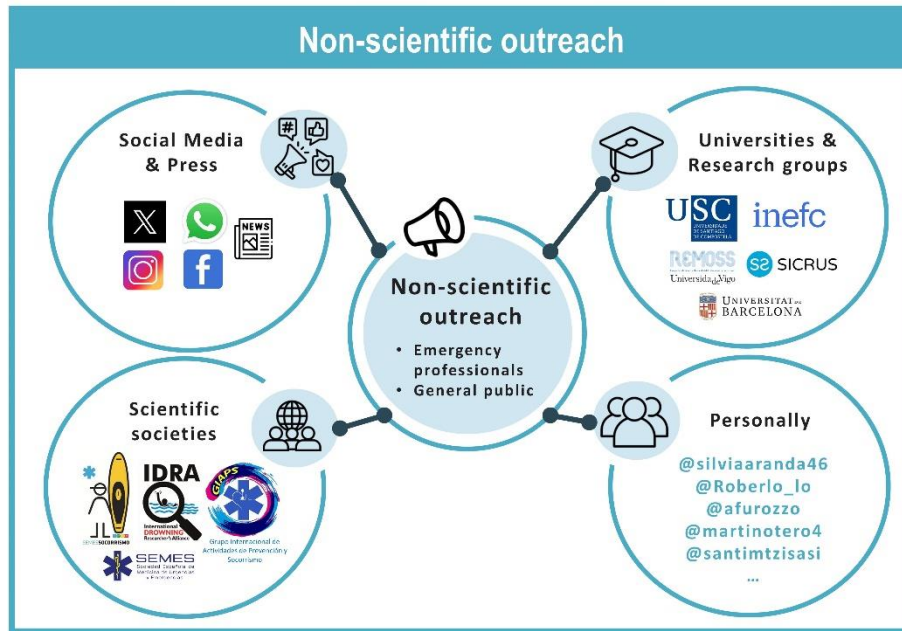


Figure 6-8. Scheme of outreach in con-scientific context. (Author-created figure)

It is worth noting the participation in two contests on scientific outreach for non-specialized audiences, in which the doctoral candidate has been awarded (Figure 6-9):

- **1st place winner in the 3MT (3 Minute Thesis) competition** organized by EDIUS (Escuela de Doutoramento Internacional) from the University of Santiago de Compostela. Presentation: Video assistance with smart glasses for the management of cardiac arrest attended by lay first aid responders. Available from: <https://www.youtube.com/watch?v=b3ISBPxY2h8>
- **1st place winner in the competition #HiloTesis** in the Gallician ranking and **finalist in the national stage** organized by Fundación Ignacio Larramendi and Red Divulga. Communication: Imagina que eres un pescador, vas navegando y tu amigo tiene un #infarto? ¿Sabrías ayudarle? ¿Y si te digo una mejor manera para salvarle la vida? Con videoasistencia con smart glasses. 2023. Available from: <https://twitter.com/RedDivulga/status/1661312902194683909?s=20>

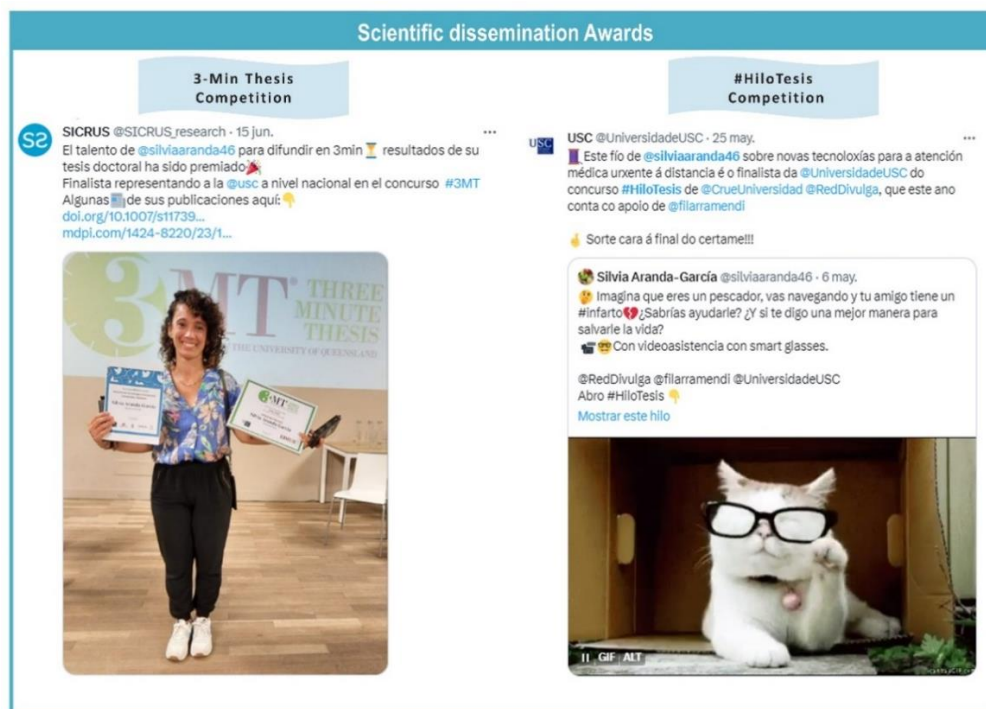


Figure 6-9. Scientific dissemination awards.

Left: Image of the award ceremony and the final of the 3MT competition posted by the SICRUS Research Group on Twitter (https://x.com/SICRUS_research/status/1669278157671747584?s=20). Right: Image of the finalist Twitter thread posted by the Universidade de Santiago de Compostela on Twitter about the #HiloTesis competition (<https://x.com/UniversidadeUSC/status/1661674868906115073?s=20>). (Author-created figure)

6.5 OTHER STUDIES CONDUCTED DURING THE THESIS DOCTORAL PERIOD

Some research studies and communications were also conducted during the doctoral thesis period, in addition to the specific results derived from the main research projects. Those are framed within the fields of out-of-hospital emergencies, simulation, basic life support, and drowning prevention.

These contributions are presented below in chronological order:

1. **Original Research Article.** Barcala-Furelos R, Sanz-Arribas I, Sánchez-Lloria P, Izquierdo V, Martínez-Isasi S, Aranda-García S, et al. **Educación sanitaria ante las falsas creencias, mitos y errores en torno a los incidentes acuáticos. Una revisión conceptual basada en evidencias.** *Educ Médica*. 2023 Sep;24(5):100821. <https://doi.org/10.1016/j.edumed.2023.100821>
2. **Communication in congress.** Berlanga-Macías C, Barcala-Furelos R, Aranda-García S, Manteiga-Urbón J, Carracedo-Rodríguez E, Martínez-Isasi S. Análisis comparativo de la

- efectividad de los torniquetes CAT y OMNAS en medio acuático. Estudio cuasi-experimental con socorristas. In: XXXIII Congreso Nacional SEMES Madrid 2023. 2023. <https://www.semes.org/wp-content/uploads/2023/06/LibroComun-SEMES2023.pdf>
3. **Original Research Article.** Alcázar Artero PM, Pardo Rios M, Greif R, Ocampo Cervantes AB, Gijón-Nogueron G, Barcala-Furelos R, **Aranda-García S**, et al. **Efficiency of virtual reality for cardiopulmonary resuscitation training of adult laypersons: A systematic review.** *Medicine (Baltimore)*. 2023 Jan 27;102(4):e32736. <https://doi.org/10.1097/MD.00000000000032736>
 4. **Original Research Article.** Sánchez-Lloria P, Barcala-Furelos R, Otero-Agra M, **Aranda-García S**, Cosido-Cobos Ó, Blanco-Prieto J, et al. **[Descriptive analysis of triggers, outcomes and the response of the health systems of child drowning in Galicia (Spain). A 17-year retrospective study].** *Rev Esp Salud Publica*. 2022 Jun 22;96. https://www.sanidad.gob.es/biblioPublic/publicaciones/recursos_propios/resp/revista_crom/VOL96/ORIGINALES/RS96C_202206048.pdf
 5. **Original Research Article.** Barcala-Furelos R, Barcala-Furelos M, Cano-Noguera F, Otero-Agra M, Alonso-Calvete A, Martínez-Isasi S, Aranda-García S, et al. **A Comparison between Three Different Techniques Considering Quality Skills, Fatigue and Hand Pain during a Prolonged Infant Resuscitation: A Cross-Over Study with Lifeguards.** *Children (Basel, Switzerland)*. 2022 Jun 17;9(6). <https://doi.org/10.3390/children9060910>
 6. **Original Research Article.** Aranda-García S, Carballo-Fazanes A, Otero-Agra M, Fernández-Méndez M, Barcala-Furelos M, Barcala-Furelos R. **Comparación de la calidad en la ventilación de socorristas nóveles y veteranos. Un estudio piloto de simulación.** *Rev Investig en Act Acuáticas*. 2022 Apr 29;6(11):37–43. <https://doi.org/10.21134/RIAA.V6I11.1646>
 7. **Original Research Article.** Santos-Folgar M, Lafuente-Filgueira P, Otero-Agra M, Fernández-Méndez F, Barcala-Furelos R, Trastoy-Quintela J, Aranda-García S, et al. **Quality of Ventilations during Infant Resuscitation: A Simulation Study Comparing Endotracheal Tube with Face Mask.** *Children (Basel, Switzerland)*. 2022;9(11):1757. <https://doi.org/10.3390/CHILDREN9111757>
 8. **Guest speaker at congress.** Aranda-García S, Barcala-Furelos R. Primeros Auxilios: utilización de recursos materiales. Congreso Internacional de Bandera Azul: sostenibilidad, salud y seguridad. Las Palmas de Gran Canaria, España: 2022. https://www.semes2022.org/uploads/docs/Libro_comunicaciones_SEMES2022.pdf
 9. **International book chapter.** Barcala-Furelos R, Aranda-García S, Palacios-Aguilar J. **Boating and Watercraft.** In: Connolly J, editor. Why swimmers drown: open water drowning survival guidelines for swimmers. Peridis Pu. Toowoomba (AUS); 2022. p. 94–108.
 10. **Original Research Article.** Aranda-García S, Herrera-Pedroviejo E, Palacios-Aguilar J. **Cómo enseñar a salvar vidas en la clase de educación física.** *EmásF Rev Digit Educ Física*. 2022;74:5–12. https://emasf.webcindario.com/Archivo_EmasF.htm

6.6 SUPERVISED DOCTORAL THESIS

During the period of this doctoral thesis, the doctoral candidate mentored a doctoral thesis. The Ph.D. candidate obtained her doctorate degree in 2011 from the University of Barcelona. Doctoral thesis mentored:

Supervised doctoral thesis presented. Barcala-Furelos M. Influencia de la resistencia de tórax en la calidad de la reanimación. Universidad Pontificia de Salamanca. Doctoral thesis directors: Sergio López García, Silvia Aranda García; 2022. https://adminpro.upsa.es/uploads/martin_barcala_furelos_40c77ee550.pdf

7. GENERAL DISCUSSION

7 GENERAL DISCUSSION

The general aim of the thesis was to assess the usability of augmented reality with video-assisted communication using smart glasses and analyze the enhancements it brings to performance and training in simulated out-of-hospital emergencies managed by laypersons.

The most significant findings from each of the three sections of the doctoral thesis (feasibility, video-assistance, and teletraining) were:

- a) It is feasible and reliable to use an intercommunication system between a dispatcher and a bystander through video calls using smart glasses to assist a layperson in responding to a simulated OHCA, specifically while navigating on a boat.
- b) Video assistance with smart glasses enables lay bystanders in emergencies to perform effectively in managing a cardiac arrest and an unplanned childbirth, and they do so better than with traditional telephone assistance or acting on their own.
- c) With augmented reality using smart glasses, bystanders can learn how to respond to a cardiac arrest, achieving equal or even better results than in traditional in-person instruction.

7.1 DISCUSSION: FEASIBILITY OF SMART GLASSES COMMUNICATION IN AN OUT-OF-HOSPITAL SETTING (WHILE SAILING ON A SMALL BOAT)

Effective communication between the dispatcher and the simulated OHCA witness while navigating in a small boat is feasible and reliable (Figure 7-1). This was demonstrated in our Article 01 in which the fishermen, who were lay in BLS, they were able to correctly follow all the steps of the protocol by communicating with the smart glasses. The communication between dispatcher and fishermen with the smart glasses was simple. Although it was the first time for these participants to use this technology, they no reported any impediment in using it. The smart glasses connect to Wi-Fi and the video call that the dispatcher will receive on his/her computer is made through an App. In addition, during the study there were no communication or connectivity problems despite the fact that the simulation scenario was in an unfavorable environment a priori because it was sailing on a boat, which can mean an inhospitable environment due to the wind, the movement of the boat, and/or the noise of the boat's engine. In this sense, we consider as a strength the bone conduction hearing mechanism of this technology, which makes it easy to receive the dispatcher's indications even with these unfavorable conditions, and promotes feasible communication.

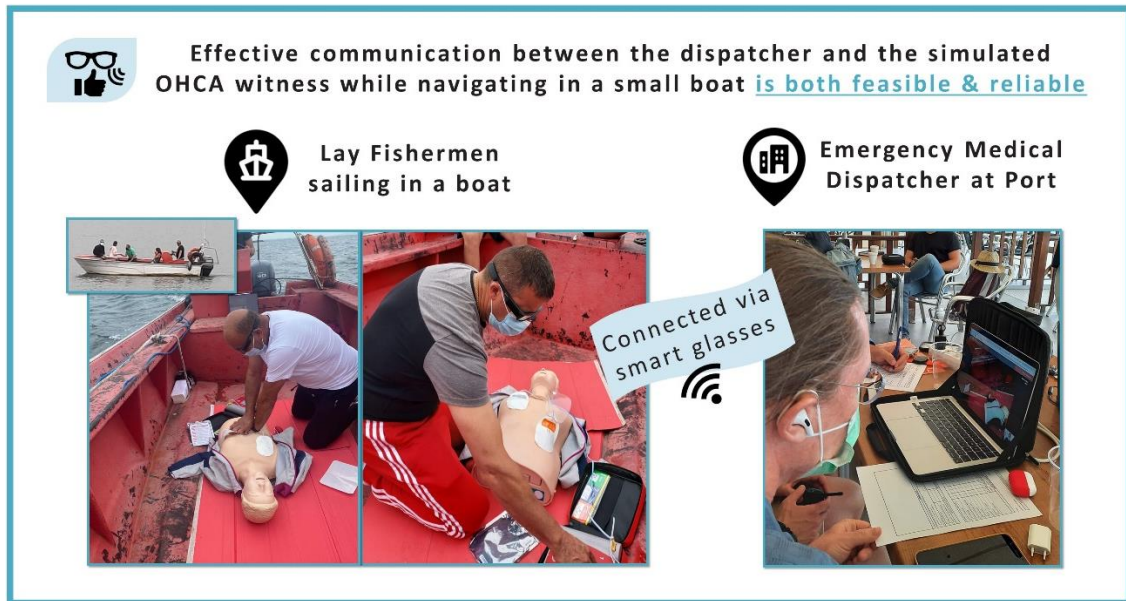


Figure 7-1. Feasibility of communication between a medical dispatcher and lay fishermen while sailing. (Author-created figure)

Furthermore, the comparison of the assessment of each variable performed by the dispatcher through the smart glasses with an on-scene instructor in the boat, suggest a high level of reliability. The authors explained it because the dispatcher could see the scene (and not just hear it as he/she would in a traditional phone call). The zenithal view provided by the smart glasses' front camera can allow the dispatcher to see what the witness sees with a good perspective for performing the ABC approach or perceiving resuscitation quality parameters.

Apart from demonstrating how communication with SG is feasible and reliable, in Article 01 we verify that the dispatcher was able to guide or correct the bystander's maneuvers in 72% of the ABC approach, including the use of the AED. Witnesses have an essential role in the treatment of OHCA [41] but they do not always take the initiative, they failing to recognize the emergency or simply feeling unable to act [42]. However, with the development of new technologies in communication [12], the identification and response in an OHCA has improved with the emergence of the emergency dispatcher [43,44]. This evolution is leading to a transition from telephone dispatchers to new forms of dispatcher based on real-time video-streaming [21,43], although there is still a lack of evidence in this regard [12] until the publication of the articles of this doctoral thesis. Smart glasses can circumvent some recognized limitations of smartphone video call assistance related to the difficulty of communication between the dispatcher and the bystander [45,46], or the number of witnesses required for the video call (at least two) [21,43].

7.2 DISCUSSION: AUGMENTED REALITY SMART GLASSES TELEASSISTANCE FOR OUT-OF-HOSPITAL EMERGENCY RESPONSE

These findings mentioned above related to Article 1, made us consider that this wearable has great potential for communication between dispatchers and laypersons, and that this video call function through smart glasses could be more widely studied to demonstrate its scope. For this purpose, we designed two studies (Articles 02 and Article 03) in which the dispatcher guides lay witnesses through this technology so that they can perform in an out-of-hospital emergency. It consists of the same type of communication as in the feasibility study, but in which the performance of the intervention group (with smart glasses) is compared with a control group. Specifically, in Article 02, the performance in a simulated OHCA was compared with traditional telephone assistance; and in Article 03, which was in an unplanned out-of-hospital childbirth attended by lifeguards (but lay in deliveries), it was compared with the performance that they would do by themselves.

Video assistance with smart glasses allows witnesses to give a good performance in an OHCA or an unplanned childbirth, and do it better than with traditional telephone assistance or helping autonomously (Figure 7-2).

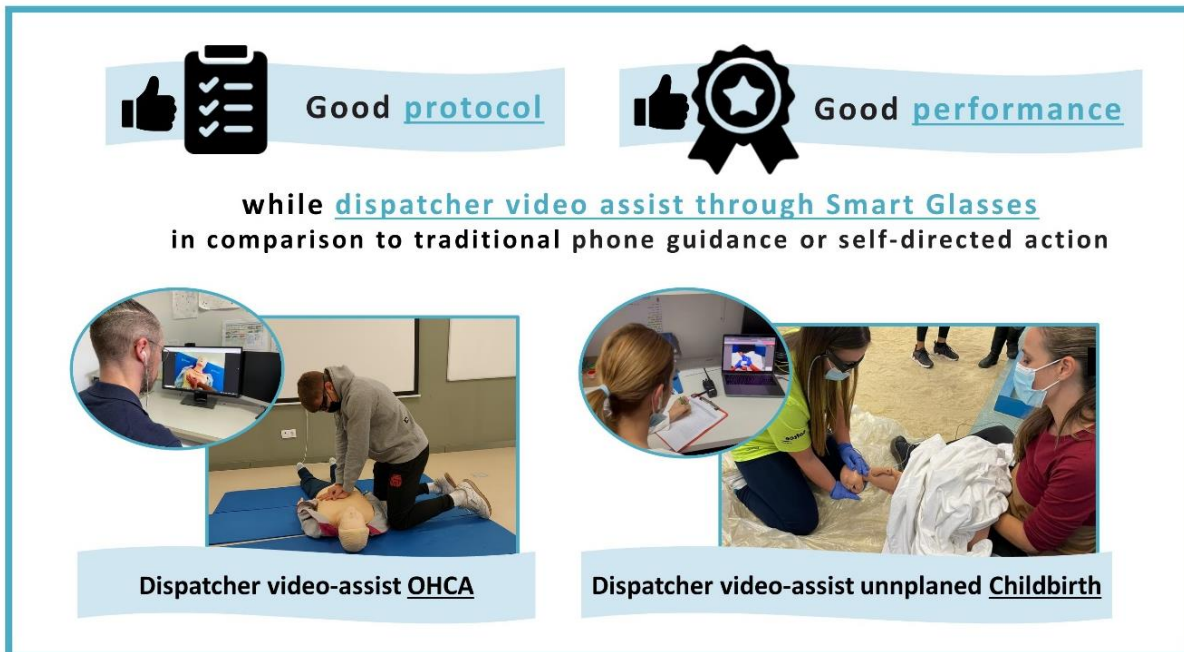


Figure 7-2. Dispatcher video-assisting out-of-hospital emergencies attended by laypeople. (Author-created figure)

In the Article 02, we designed a pilot study, the first of its kind, to determine whether dispatcher assistance with live video streaming through smart glasses (smart glasses-video assistance group: SG-VA) might offer significant advantages over telephone instruction only (smartphone-audio assistance group: SP-AA). The main findings were that the use of smart glasses was associated with higher rates of correct BLS, better use of the AED, and faster initiation of CPR, while quality of chest compressions was acceptable in both conditions.

Most SG-VA rescuers but none of the controls correctly completed all the steps of the BLS protocol ($p < 0.001$). Correct application of this protocol on the scene of an OHCA event is crucial for assessing the victim, alerting the emergency medical services, commencing CPR, and ensuring prompt arrival of the AED [4]. Practically all the SG-VA rescuers (13/14) opened the airway properly and checked breathing (while only 5 of the 14 in the SP-AA group opened the airway and 8 checked breathing). Assessment of breathing, particularly when this is agonal, can be difficult for laypeople [47,48] and dispatchers on the other end of the telephone [19], but our preliminary findings show that smart glasses could aid this assessment.

Communication via this wearable was also associated with improved AED use. This positive results were probably because the dispatcher was able to visually check correct pad positioning and make sure that nobody was touching the patient when the shock was delivered [49,50]. The superior performance observed in the SG-VA group is probably linked to the dispatcher's ability to adapt his feedback to what he/she was seeing in real time on his computer screen thanks to the images streamed from the front-facing camera placed on the smart glasses. He/she would have been able, for example, to see when the participant had wrongly positioned an AED pad or had not performed the head tilt-chin lift maneuver correctly. By contrast, in the SP-AA group, he/she had to rely on what the rescuer was telling him/her. So, based on these results, compared with audio communication over a smartphone, video streaming through smart glasses improved the transfer of dispatcher-bystander information.

To determine if this type of communication could also be useful in other types of out-of-hospital emergencies, specifically in an unplanned out-of-hospital birth at a beach, we designed Article 03. In this study, we hypothesized that interactive guidance by a midwife visualizing in real time what a layperson (lifeguard lay in childbirths) transmits to her/his through smart glasses will allow this person to perform the appropriate procedures. In this case, compared to how they acted on their own, without the help of a dispatcher.

In this sense, our major finding was that when the midwife video-assists with smart glasses, the lay rescuer in childbirth assistance is able to correctly perform the protocol for unplanned out-of-hospital birth. Participants are able to follow the sequence of actions and perform the different steps correctly even though it was the first time they had done. Improvements in video-assisted performance with SG occurred in both technical skills (those directly related to procedural birth assistance and which without assistance would be difficult to provide good care for either the mother or the baby) and non-technical skills (those related to communication and essential in the management of the stressful situation). When a childbirth occurs in an unplanned way, a process that should be natural, can become an emergency with risks for mother and baby [9] and that is why it is important to study new ways in which the dispatcher can better assist the bystander. Based on our findings, this kind of video assistance with smart glasses could be useful for this purpose, even if the witness has some duty to assist (lifeguards, police, firefighters...).

Regarding **technical skills**, the video-assisted lifeguards with SG performed significantly better than CG including the assessment of the stage of labor, the assistance during the expulsive phase, and the newborn care. The midwife at the simulated emergency center guided the lifeguard to ask about the pushing feeling, assess the stage of labor, encourages pushing, or to protect the perineum during the expulsive phase. Many vaginal deliveries are with perineal trauma which is associated with morbidity with pain, urinary or fecal incontinence [51–53]. The

World Health Organization [54] and current protocols [55,56] recommends the active protection of the perineum to reduce perineal injury [57]. In our study, the midwife's SG-dispatcher allowed 90% of the participants with SG to correctly protect the perineum compared to 0% of those who acted autonomously.

When the third stage of labor has ended, the care of the newborn obtains special importance. Hypothermia is the most common morbidity in the unplanned out-of-hospital births (occurs in 50% of cases) [58]. A good strategy to prevent it is to dry and cover the baby and to place him/her skin-to-skin on the mother's bare chest or abdomen [59,60]. In our study, the vast majority of lifeguards (80%) assisted with SG placed the baby skin-to-skin and almost all dried and covered the baby's body and head. However, none of CG participants placed the newborn skin-to-skin and only one of them dried/covered the baby. Therefore, communication with smart glasses between the lifeguard and midwife was useful for the technical care skills of both the mother and the baby.

Something similar happened with **non-technical skills**, in which the lifeguard who acted without assistance did not have effective communication with the pregnant woman, and with SGs, the midwife was able to video-assist the rescuers and nearly all of them performed the non-technical skills perfectly. These non-technical skills (identify themselves, explain the situation, ask permission to touch the vulva, reassured the woman...) are fundamental for the respectful accompaniment of the woman so that the experience of childbirth can be positive and empowering instead of traumatizing [61,62]. A good communication and reassurance are especially important in unplanned out-of-hospital childbirths because pregnant women report fear, poor interpersonal skills of the people assisting them, and lack of consent for certain procedures such as vulvar assessment or active protection of the perineum [63,64]. And this occurred in the first responders assisted with SG: the dispatcher encouraged better accompaniment of the woman in this simulated vital moment.

In both articles related to video assistance with SG, there were two aspects that were unique for Article 02 and Article 03. The first was in relation to the **performing time** when attending the OHCA event (Article 02), as survival and functional outcomes are time-dependent [65], it is not only important to perform well, but also to do it quickly. We consider it very positive that the lack of previous experience with smart glasses did not result in any delays in care provision by SG-VA. This finding is especially interesting due that previous studies have found that dispatcher-assisted BLS via a smartphone video call is associated with important delays [12,13]. The second aspect was that in the Article 03, unlike Article 02, in addition to verbal instructions, the dispatcher also **sent images** so that the participants could see how they should assist in the third stage of labor. These images were projected onto the right lens of the SG themselves and participants stated that they were very helpful ($8.6 \pm 2.1/10$) in understanding how they should position their hands to protect the perineum or to facilitate the extraction of the baby's shoulders (Figure 7-3). And, it is highlighted that these technical skills were performed by the participants with SG significantly better than in the control condition.

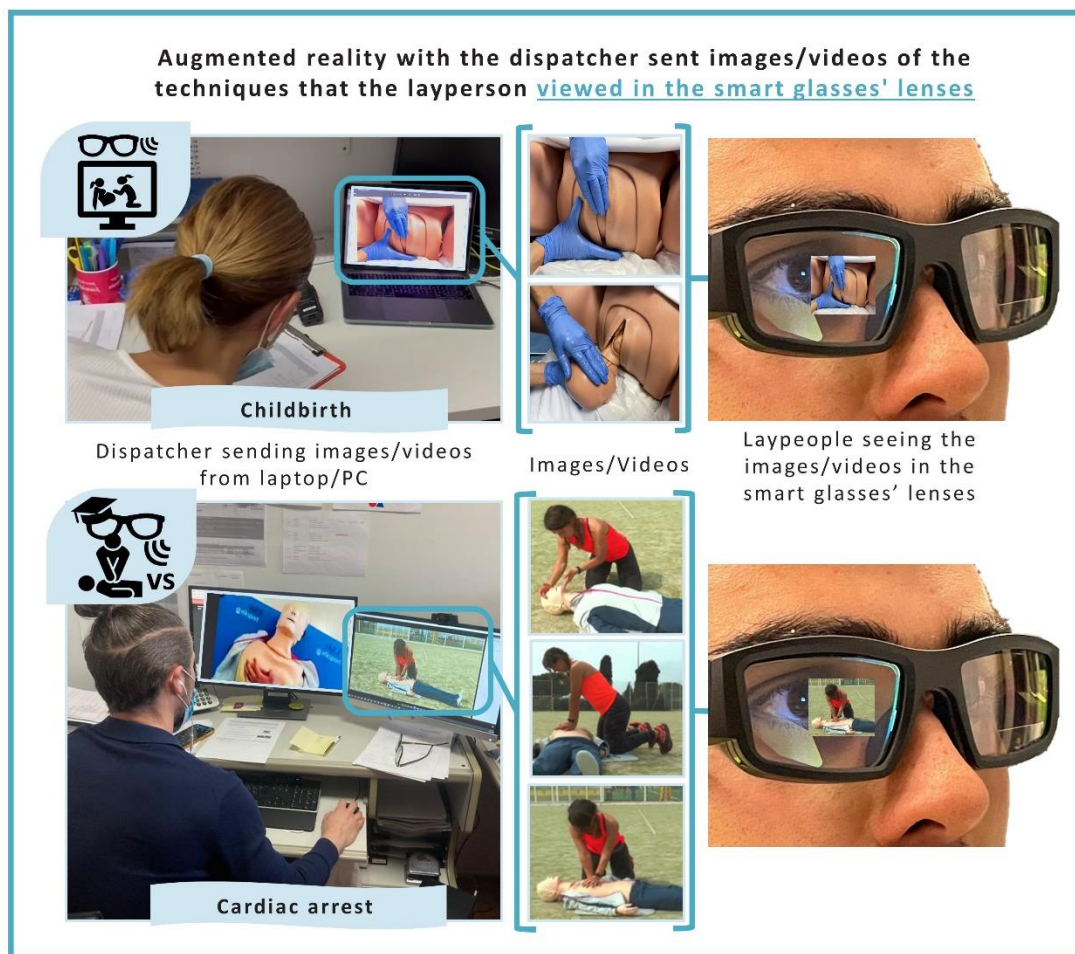


Figure 7-3. Viewing images and videos on the lenses of smart glasses.
(Author-created figure)

In both articles on video assistance with smart glasses for the care of an out-of-hospital emergency (Articles 02 and 03), the positive results of the intervention group throughout the protocol could be explained by the good communication between the bystander and the dispatcher through the SG. The dispatcher was able to guide and correct just-in-time the rescuer based on what he/she **saw and also heard** in the video call. Our experience suggests that smart glasses result in improved performing because the bystander can show the dispatcher what he/she is seeing without needing to use his/her hands, which are which are completely free to perform the different technical skills of the BLS or childbirth.

Furthermore, the participants of both articles had sufficient mastery of the smart glasses with a **familiarization** of less than 5 minutes with the smart glasses. With this brief familiarization session, the wearers rated the glasses as very being easy to use (with a median score of 2 out of 10). Besides, in both pilot studies, participants stated that **the use** of the smart glass's technology was of very low difficulty (median score, 2/10 in Article 02, and 1.2/10 in Article 03).

In both pilot studies, it is verified how this kind of telemedicine through smart glasses can be a powerful communication device in which an expert in emergencies can remotely video-assist a layperson. Based on these findings and given the potential of this new communication tool, we questioned whether communication through this wearable device could be beneficial for remote training in basic life support. We will address this question in the following three articles: Article 04, Article 05, and Article 06.

7.3 DISCUSSION: AUGMENTED REALITY TRAINING WITH SMART GLASSES IN BLS

Teaching BLS to as many laypeople as possible is a goal aimed at preventing the adverse outcomes of OHCA. In some cases and settings, accessing this type of education can be challenging, which is why it might be interesting to explore training using new technologies, in line with the recommendations of Greif et al. [22] in the "Education for Resuscitation" chapter of the European Resuscitation Council guidelines published in 2021. However, the new technological tools, such as augmented reality, should not be used without a previous rigorous evaluation of their feasibility, advantages, and disadvantages. For this reason, we consider it essential to evaluate smart glasses (SG) as a learning tool to create an augmented reality environment before proceeding with their routine use in training.

In a Letter to the Editor (Article 04), we emphasize the potential of this type of communication to create an augmented reality environment, where the instructor could, to some extent, "teleport" virtually to the scene through the smart glasses' video call. This possibility could facilitate remote basic life support (BLS) training, with the added benefit of real-time corrections, as the instructor would see the same as the student or even display images in the glasses illustrating the various techniques to be performed. This could offer an alternative way of learning BLS distinct from traditional face-to-face education.

In Articles 05 and 06, we explored the application of augmented reality with smart glasses for training individuals with no prior experience in responding to OHCA. In Article 05, we examined how participating in a simulated OHCA response, aided by video communication through smart glasses, enhances participant learning. Conversely, in Article 06, our emphasis was on creating a concise BLS training program utilizing augmented reality with smart glasses, providing both the instructor and the student with a real-time shared view through the smart glasses. Moreover, students could view images illustrating various techniques to be performed in real-time via their smart glasses. In this latter article, we conducted a comparative analysis of SVB learning using augmented reality with smart glasses versus a traditional face-to-face methodology, employing a quasi-experimental design (Figure 7-4).



Figure 7-4. Training with augmented reality using smart glasses compared to traditional training has shown effectiveness and could be of interest, especially in remote locations.
(Author-created figure)

These two articles of this thesis highlight that, through training using this wearable device in video calls with the instructor, laypeople can acquire a robust set of skills related to the BLS protocol, the use of an AED, and the precise execution of certain quality parameters in resuscitation, along with achieving optimal response times. Furthermore, in the quasi-experimental study, we compared learning with a control group that received traditional instruction and found that learning with smart glasses was not inferior to the traditional method in any of the evaluated variables. Additionally, participants who learned with smart glasses demonstrated significantly superior performance in three specific aspects: assessment of breathing, ensuring that no one touches the victim before defibrillation, and achieving better recoil of chest compressions. The assessment of breathing is crucial for determining whether the victim is in cardiac arrest and requires CPR and AED use [4]. Ensuring scene safety before defibrillation is important for the safety of the rescuer and the effectiveness of the shock [49,50]. Furthermore, the improvement in chest compression recoil achieved with smart glasses (53% more chest compressions with adequate recoil compared to the control group) is a critical parameter from a clinical perspective, as it allows for complete chest recoil, thereby contributing to the maintenance of adequate cardiac output.

Apart from evaluating the quality of the execution of the different techniques involved in BLS, we also analyzed response times. In OHCA situations, the speed of intervention is crucial, as survival and clinical outcomes are directly correlated with time [66]. In this context, augmented reality could also be considered advantageous due to the rapidity of resuscitation, as the time to AED shock and the first chest compression was less than 2 minutes from the start of the scenario [66].

Given that both interventions were comparable in terms of duration, content, and personalized corrections (ratio 1 teacher:1 student), the exact mechanisms explaining the favorable differences observed in favor of smart glasses are not precisely known. However, it is plausible

that this advantage may be related to the ability to visualize real-time animated images through the smart glasses (Figure 7-3). Although the initial purpose of sending these images to the smart glasses was to demonstrate BLS skills to the participants, such as airway opening or assessment of breathing, it is possible that this motivated them to pay special attention to these techniques and, as a result, strive for more effective execution. In any case, it is highly encouraging that remote training guided by smart glasses achieves results that are not inferior and, in some cases, superior to what is considered the gold standard for individualized in-person training. This positions this type of training, which utilizes augmented reality through video calls with smart glasses, as a novel and valid method for BLS education.

Consistent with our findings, prior research has assessed the impact of other technological methods, such as virtual and augmented reality, on the quality of CPR. These alternative approaches, akin to the use of smart glasses, exhibit promise but necessitate further investigation to establish robust recommendations [37,67,68]. Nevertheless, due to their extensive applicability and diminished requirement for the mobilization of human and material resources, smart glasses-based training may emerge as a formalized and very-brief method for delivering BLS instruction. From a practical standpoint, this form of training could be particularly advantageous in remote or rural regions characterized by reliable WiFi connectivity but limited access to resuscitation education, often due to cost or geographical constraints [69]. This would enable personalized training, aligning with the guidelines put forth by the ERC [3], and it could serve as the foundation for long-term educational programs with regular refreshes.

7.4 PRACTICAL IMPLICACIONES

This compilation of publications presents a series of studies that generate direct implications for practice, closely linked to our findings. Some of these implications are quite immediately applicable, while others, in turn, pave the way for a future where communication through smart glasses may provide more favorable augmented reality environments for even more effective practice in improving emergency care and training.

Our findings demonstrate that communication using smart glasses is feasible and can be particularly valuable for assisting in out-of-hospital emergencies when attended by laypersons. When an emergency occurs outside of a medical facility and there is no healthcare expert available to provide assistance, the bystander who witnesses it does whatever is within their capabilities to help. Despite efforts to facilitate effective assistance between the emergency dispatcher and the bystander, the optimal method of enhancing communication between both for improved performance has yet to be identified. This could be due to either audio-only telephonic assistance not being as effective as expected or initial trials of smartphone video calls discouraging their use due to potential delays in response, connectivity issues, or the need for more than one person to operate the device. The findings of the video assistance studies in this thesis are promising because they demonstrate a form of communication with smart glasses in which the emergency expert can directly see and hear what is happening at the scene. This enables a more precise adaptation of instructions provided to the layperson until the arrival of the ambulance. This implication for practice is of particular interest to any layperson who, understandably, would require assistance when intervening with patients. Furthermore, it also holds great significance for healthcare professionals such as lifeguards, healthcare technicians,

paramedics, nurses, and physicians, who may find themselves in critical situations outside their area of specialization or in environments where they must act independently and without access to medical supplies, such as an emergency outside their usual workplace.

It's important to note that these findings are based on the use of commercially available smart glasses that were not specifically designed for such purposes. Any model of smart glasses equipped with a video camera and allowing bidirectional communication via video calls could offer comparable utility to what we have observed. It's worth highlighting that the positive results are partly attributed to the inherent features of smart glasses, such as ease of Wi-Fi connectivity, the camera's ability to transmit real-time video, high-quality audio through bone conduction (remaining clear even in noisy environments, such as the background noise of a boat engine while sailing), and the capacity to receive visual instructions directly on the glasses' lenses, which facilitates the execution of necessary techniques. It's reasonable to assume that communication could be even more effective with a wearable device designed specifically for this purpose. Such smart glasses could provide more advanced and real-time augmented reality with significant implications for critical care. With certain design modifications, response times could be improved, such as automatically initiating communication with emergency services upon wearing the glasses, or enhancing the quality of care by integrating accessories specially designed for out-of-hospital emergency situations. These add-ons could include real-time visualization of the protocol of action on the glasses' lenses or improved guidance for techniques using artificial intelligence, such as instructions on electrode placement for AEDs or monitoring the rhythm of chest compressions. All of these implications revolve around the enhancements that this wearable device offers in terms of **real-time communication** and the integration of **visual instructions**.

It is worth noting that this innovative communication system with smart glasses has practical implications of relevance in various domains. Firstly, there is an implication related to **navigation and location**. Smart glasses are equipped with geolocation functionality that could expedite the arrival of response teams to the emergency scene. This could lead to more efficient responses in critical situations. Secondly, there is the implication of **resource optimization**. Since the teleoperator has the ability to visualize the patient in real-time through the smart glasses, one would expect that decision-making would be facilitated, potentially resulting in a more precise allocation of resources, such as selecting the type of response vehicle or determining the necessary medical personnel to address the emergency efficiently. Thirdly, there is the implication associated with **data recording and documentation**. Smart glasses allow for image capture and video recording during medical care, enabling subsequent review of the intervention. This visual documentation could contribute to healthcare professionals' training and continuous improvement of emergency response protocols. Fourthly, this type of communication could optimize access to **critical real-time information**. Smart glasses can have the same functions as a smartphone, which could provide healthcare professionals with instant access to vital information, thereby expediting decision-making and ensuring the application of appropriate procedures at the right moment. Finally, being an Android-based device, it allows for the installation of **software and artificial intelligence** tools that can enhance the augmented reality environment, offering superimposed visual instructions for the

proper placement of AED's electrodes or the appropriate chest compressions rate during resuscitation. This would have significant implications for critical care.

This innovative communication technology could acquire particular relevance when considering its strategic **implementation in critical locations or services** where communication between the emergency expert and the user of smart glasses can be crucial. Such communication could be established with either the emergency medical operator or the user's own emergency center. To provide effective assistance to occasional lay witnesses, the installation of smart glasses in highly congested or challenging-access locations, where significant delays in the arrival of healthcare services are expected, could be of great utility. An example of this could be their integration as a cardioprotection tool alongside AEDs in villages or remote areas, or in combination with AEDs transported by drones to hard-to-reach areas. Moreover, these glasses could be incorporated as a means of communication for first responders or emergency professionals who need to consult with an expert in situations where they lack certain skills, such as diagnosis and treatment. This could be especially valuable for lifeguards at the beach, nurses in advanced life support ambulances, or cabin crew in aircraft who require guidance in the care of critical patients and seek to establish more effective communication with their emergency center, as an alternative to traditional methods like smartphones or communication radios.

On the other hand, this communication system, given its broad applicability and minimal requirement for mobilizing human and material resources in **BLS training programs**, could establish itself as a structured method of very brief training for cardiopulmonary resuscitation care. In terms of practical applicability, this type of training could be particularly valuable for remote or rural areas with good internet connectivity but limited access to resuscitation training due to cost or geographical constraints [69]. This type of remote teaching with smart glasses, as an out-of-classroom method, could enable individualized training tailored to the needs of each student, promoting an alternative and enjoyable learning experience through the use of the wearable technology, in line with what is proposed by the European Resuscitation Council (ERC) [3]. The instructor's ability to visualize the student's perspective in real-time through subjective vision translates into the potential to provide highly individualized corrections. This is manifested through verbal corrections via audio communication, as well as visual corrections by sending images or videos directly to the lenses of the student's smart glasses. This allows, for example, the student to observe in detail how chest compressions should be performed or how to execute the airway opening maneuver using the chin-lift technique. The results obtained in our studies on teaching BLS using augmented reality via smart glasses can serve as a crucial starting point for the development of long-term educational programs that include periodic and repetitive updates, ensuring continuous and effective learning.

The practical implications emerging from the compilation of publications in this thesis are exceedingly intriguing and point to the potential of using smart glasses as a communication tool in out-of-hospital emergency situations. Our findings have the potential to mark a significant milestone in the tangible improvement of care in critical situations outside of hospital settings. This augmented reality technology through smart glasses is envisioned as a resource that could play an essential role in both training and the provision of emergency services, promoting a

more effective response, and ultimately contributing to the possibility of saving lives in emergency situations.

7.5 LIMITATIONS

These articles were not exempt from limitations, which were duly acknowledged in all the thesis articles. There are several limitations attributed to the design itself, the use of smart glasses as a video communication wearable, the interpretation of results based on participant characteristics, and the future implementation of our findings.

Regarding the limitations inherent to the **design**, since this is a novel topic in the field of research on new communication technologies in out-of-hospital emergencies, all articles were designed as **pilots**. For this reason, a small sample **size** was used, and a larger number of participants could enhance statistical power and yield more significant differences. Also, it is possible that results may differ with larger sample sizes. Furthermore, the scenarios were **simulated**, which entails its specific limitations by design. Although it has been shown that at least some of the skills acquired through simulation training are transferred to real practice [70,71].

Concerning limitations related to the **use of smart glasses** themselves, it is important to consider that in all our studies, the **Wi-Fi** connection used allowed the research to be conducted under optimal communication conditions. This held true even in studies conducted in out-of-hospital settings, such as while navigating on a boat. However, it cannot be ruled out that real-world circumstances with connectivity limitations could hinder their applicability. Additionally, it is worth noting that the **battery** life of smart glasses is limited, so progress in research demonstrating the benefits of these devices may favor their development and compensate for this limitation.

When interpreting the results, the profile of the **participants** must be considered. Our findings are contextualized with a specific typology of participants. They were laypeople with no prior knowledge in the emergency to study, so we value as very positive our findings. However, it must be taken into account that in some of the studies the participants were young university students of health and/or sports sciences. In this case, a certain ease of learning can be assumed for them to use the smart glasses wearable, and it could be assumed that they have a certain ability for learning simple procedures such as BLS, and motor skills such as chest compressions [72], so our results cannot be extrapolated to other profiles of people.

Lastly, the **implementation** of the findings from this thesis may pose challenges due to the integration of this communication technology into both emergency systems and training programs. Since these are pilot studies, their applicability in real situations should be carefully evaluated before implementation. Additionally, it is important to consider that the use of this type of telemedicine requires good connectivity, which may limit its use in remote locations or in some areas of buildings with poor internet connection (such as basements).

8. CONCLUSIONS

8 GENERAL CONCLUSIONS

The conclusions of this thesis are organized into three sections, corresponding to the three hypotheses developed in the various articles of this compilation of publications. The first section deals with the usability of smart glasses in out-of-hospital settings. The second section focuses on video assistance using smart glasses for out-of-hospital emergency care, specifically in cases of cardiac arrest attended by laypersons and unplanned childbirth attended by lifeguards. Finally, the third section addresses cardiopulmonary resuscitation (CPR) training through augmented reality with smart glasses. Subsequently, we shall proceed to elucidate the conclusions drawn from this doctoral thesis.

8.1 CONCLUSIONS ACCORDING TO H1 AND O1

The use of smart glasses in an out-of-hospital emergency scenario is feasible even while sailing on a boat, as long as there is good Wi-Fi connectivity available.

Communication between the emergency dispatcher and the witness is seamless and is especially helpful during the dispatch of the ABC approach and AED use.

8.2 CONCLUSIONS ACCORDING TO H2 AND O2

Compared with audio communication over a smartphone, video streaming through smart glasses improved the transfer of dispatcher-bystander information and was associated with better BLS performance and AED use and comparable chest compression quality and performance times.

In simulated, unplanned, uncomplicated, remote birth conditions, telemedicine through video assistance with SG is feasible for a lifeguard with no knowledge of childbirth care to perform according to the recommendations for unplanned, out-of-hospital birth.

The communication of the midwife with the lay attendant by talking and sending images to the SG may be of significant benefit both in relation to technical (steps of the recommended sequence) and non-technical skills (support to the laboring woman).

8.3 CONCLUSIONS ACCORDING TO H3 AND O3

Augmented reality teletraining via video call using smart glasses can be a valuable educational tool for learning BLS. Specifically, a very brief training experiencing a simulation of videossisted cardiac arrest care with smart glasses has demonstrated promising results as an educational method for learning the BLS, the use of the AED, and some skills to perform BLS.

Very brief training in BLS-AED using smart glasses for laypersons could potentially be as effective as traditional teaching methods, or even more advantageous in certain aspects of the BLS protocol and the quality of chest compressions. This advantage may be attributed to the real-time image visualization capability that supports the BLS protocol.

The use of augmented reality-based teaching should be considered for BLS training. Nevertheless, caution should be exercised in extrapolating findings, and further research is needed to assess new theoretical and practical teaching methodologies that can help both laypersons and healthcare professionals achieve and maintain high-quality chest compressions.

9. FUTURE PERSPECTIVES BASED ON THIS RESEARCH



9 FUTURE PERSPECTIVES BASED ON THIS RESEARCH

These lines of research could provide additional data to support future interventions and policies in the field of healthcare and training in emergency situations, with a particular focus on out-of-hospital emergencies attended to by laypersons. The future areas based on this research focus on four basic topics:

1. **Synergies with other technologies.** Exploring synergies between smart glasses and other technologies to enhance assistance and training in emergencies is a promising area of research. Smart glasses can be integrated with drones (for swift transportation), AEDs (to better guide the emergency operator), software/Apps (which can be installed just like on a smartphone), and artificial intelligence. The integration of artificial intelligence into smart glasses could be used to guide and assist emergency witnesses in real-time. For instance, this technology could direct the action protocol, aid in identifying cardiac arrest, offer guidance on proper AED pad placement, and provide immediate feedback on resuscitation quality (rate, depth, etc.). This same interaction would be valuable in education, where artificial intelligence could primarily guide the learning of emergency response skills, offering instant feedback to enhance real-time training. This approach offers significant potential to enhance care and training in critical situations.
2. **Development of smart glasses and implementation in emergency systems.** The development of smart glasses specifically designed for intervention in out-of-hospital emergencies could improve communication with emergency services. Our studies focused on simulated environments with a simulated emergency call center. Studies are needed to implement this type of communication with video calls and the receipt of images/videos through the glasses' optics in real emergency call centers. Based on our results, it could be interesting to study the incorporation of this type of new communication technology, especially in areas where delayed response times are expected for the arrival of emergency services (e.g., remote locations such as rural areas, fishing boats, or airplanes far from ambulances and hospitals). Although the future implementation of this technology may represent a significant opportunity to improve assistance in emergencies attended by non-professionals, it will also pose a challenge in its implementation. It will be necessary to consider the opinions of the dispatcher, the first responder, and the patient for the acceptability of this technology. Additionally, pertinent ethical aspects related to privacy, security, fairness, and accountability must be considered to uphold the rights of individuals.
3. **Exploration of augmented reality teletraining with smart glasses for optimal learning and retention.** In our studies, we have demonstrated the potential of this type of communication for BLS training. However, it is relevant to delve into the optimization of individualized educational programs for this method of instruction outside the classroom through the use of this wearable technology. In this research process, crucial aspects such as

the duration of sessions with effective training time, frequency, and the integrated use of feedback systems for the quality of resuscitation should be considered. Additionally, it is important to evaluate how these variables influence the learning and retention process, compared to established educational methods.

4. **Expansion of sample and study in other contexts.** These pilot studies have laid the groundwork for scientific evidence, and it would be beneficial to conduct further research with a larger participant sample to confirm the contribution of smart glasses to telemedicine and training in out-of-hospital emergency care. Furthermore, utilizing this form of communication for assistance and/or training in various other contexts would be intriguing, considering one of the advantages of this communication is its ability to occur in any location with good WiFi connectivity (locations, user profile...).

10. REFERENCES

10 REFERENCES

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APPENDIX

APPENDIX I: PERMISSION FOR REPRODUCTION AND/OR SCREENSHOTS OF THE FREE FULL TEXT

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Are smart glasses feasible for dispatch prehospital assistance during on-boat cardiac arrest? A pilot simulation study with fishermen

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Abstract


The aim of the study was to explore feasibility of basic life support (BLS) guided through smart glasses (SGs) when assisting fishermen bystanders. Twelve participants assisted a simulated out-of-hospital cardiac arrest on a fishing boat assisted by the dispatcher through the SGs. The SGs were connected to make video calls. Feasibility was assessed whether or not they needed help from the dispatcher. BLS-AED steps, time to first shock/compression, and CPR's quality (hands-only) during 2 consecutive minutes (1st minute without dispatcher feedback, 2nd with dispatcher feedback) were analyzed. Reliability was analyzed by comparing the assessment of variables performed by the dispatcher

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Randomized Controlled Trial > Sensors (Basel). 2022 Dec 30;23(1):409. doi: 10.3390/s23010409.

"Dispatcher, Can You Help Me? A Woman Is Giving Birth". A Pilot Study of Remote Video Assistance with Smart Glasses

Silvia Aranda-García^{1 2}, Myriam Santos-Folgar^{3 4 5}, Felipe Fernández-Méndez^{2 3 4}, Roberto Barcala-Furelos^{2 3}, Manuel Pardo Ríos⁶, Encarna Hernández Sánchez⁶, Lucía Varela-Varela⁵, Silvia San Román-Mata⁷, Antonio Rodríguez-Núñez^{2 8 9 10}

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PMID: 36617008 PMCID: PMC9824362 DOI: 10.3390/s23010409
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Abstract

Smart glasses (SG) could be a breakthrough in emergency situations, so the aim of this work was to assess the potential benefits of teleassistance with smart glasses (SG) from a midwife to a lifeguard in a simulated, unplanned, out-of-hospital birth (OHB). Thirty-eight lifeguards were randomized into SG and control (CG) groups. All participants were required to act in a simulated imminent childbirth with a maternal–fetal simulator (PROMPT Flex, Laerdal, Norway). The CG acted autonomously, while the SG group was video-assisted by a midwife through SG (Vuzix Blade, New York, NY, USA). The video

Screenshots of the acceptance of Article 04 (letter to editor) – Augmented reality smart glasses. A new resuscitation training tool or a worthless gadget?

IAEM: Your manuscript entitled Augmented reality smart glasses. A new resuscitation training tool or a worthless gadget? - [EMID:e634460362138243]  Recibidos x



Internal and Emergency Medicine (IAEM) <em@editorialmanager.com>
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CC: "Santiago Martínez-Isasi" santiago.martinez.isasi@usc.es, "Roberto Barcala-Furelos" roberto.barcala.furelos@gmail.com, "Marc Darné" marcdarne123@outlook.com, "Antonio Rodríguez-Núñez" antonio.rodriguez.nunez@usc.es

Dear Dr. Aranda-García,

We are pleased to inform you that your revised manuscript entitled "Augmented reality smart glasses. A new resuscitation training tool or a worthless gadget?" ([re.no](#), IAEM-D-23-00985R1) has been accepted for publication in Internal and Emergency Medicine

We plan to publish this paper as early as possible.

Thanking you for your collaboration, we send you best regards,

Sincerely yours,
Piero Portincasa
Internal and Emergency Medicine

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Resusc Plus. 2023 Apr 18;14:100391. doi: 10.1016/j.resplu.2023.100391. eCollection 2023 Jun.

Augmented reality training in basic life support with the help of smart glasses. A pilot study

Silvia Aranda-García^{1 2}, Martín Otero-Agra^{3 4}, Felipe Fernández-Méndez^{2 3 4}, Ernesto Herrera-Pedroviejo⁵, Marc Darné¹, Roberto Barcala-Furelos^{2 3}, Antonio Rodríguez-Núñez^{2 6 7 8}

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PMID: 37128627 PMCID: PMC10148024 DOI: 10.1016/j.resplu.2023.100391
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Abstract

Introduction: Laypeople should be trained in basic life support and traditional and innovative methodologies may help to obtain this goal. However, there is a knowledge gap about the ideal basic life support training methods. Smart glasses could have a role facilitating laypeople learning of basic life support.

Aim: To analyze the potential impact on basic life support learning of a very brief training supported by smart glasses video communication.

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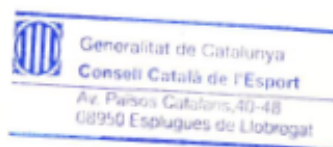


DR. RAMON BALIUS MATAS,
ACTING AS SECRETARY OF THE ETHICS COMMITTEE
FOR CLINICAL RESEARCH
OF THE CATALAN SPORTS COUNCIL.

CERTIFIES

At the meeting on August 2, 2021, the Ethics Committee agreed to favorably assess the project presented by Silvia Aranda-García (PhD), number 022/CEICGC/2021, entitled “¿Las smartglasses ayudan a salvar vidas? Actuación del lego en emergencias y catástrofes urbanas?”.

We note this favorable assessment for the appropriate purposes.



Dr. Ramon Balius Matas
Esplugues de Llobregat, August 10, 2021

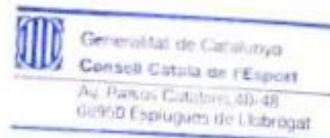


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CERTIFIES

At the meeting on November 7, 2022, the Ethics Committee agreed to favorably assess the project presented by Sivia Aranda García, number 033/CEICGC/2022, "Hearts too young to die: prevention of sudden death in sport through teletraining assisted by smart glasses".

We note this favorable assessment for the appropriate purposes.



A handwritten signature in blue ink, appearing to be "R. Balius Matas", written over a horizontal line.

Dr. Ramon Balius Matas
Esplugues de Llobregat, November 7, 2022

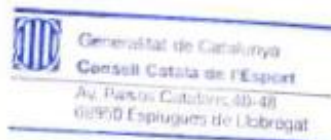


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CERTIFIES

At the meeting on October 10, 2022, the Ethics Committee agreed to favorably assess the project presented by Silvia Aranda García, number 033/CEICGC/2022, "Unplanned out-of-hospital delivery video-assisted by smart glasses and attended by lifeguards on the beach. Experimental study".

We note this favorable assessment for the appropriate purposes.



A handwritten signature in blue ink, appearing to be "Ramon Balius Matas", written over a horizontal line.

Dr. Ramon Balius Matas
Espugues de Llobregat, October 10, 2022

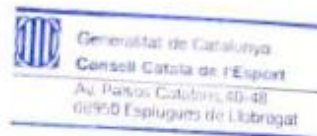


DR. RAMON BALIUS MATAS,
ACTING AS SECRETARY OF THE ETHICS COMMITTEE
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CERTIFIES

At the meeting on February 1, 2023, the Ethics Committee agreed to favorably assess the project presented by Silvia Aranda-García, number 003/CEICGC/2023, "Training Basic Life Support with the help of smart glasses. A pilot study with laypeople".

We note this favorable assessment for the appropriate purposes.



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Dr. Ramon Balius Matas
Esplugues de Llobregat, February 1, 2023

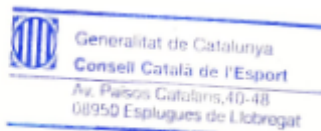


DR. RAMON BALIUS MATAS,
ACTING AS SECRETARY OF THE ETHICS COMMITTEE
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CERTIFIES

At the meeting on July 29, 2022, the Ethics Committee agreed to favorably assess the project presented by Silvia Aranda-García, number 026/CEICGC/2022, "Very brief basic life support and AED teletraining with video call through smart glasses. An experimental study with laypeople".

We note this favorable assessment for the appropriate purposes.



A handwritten signature in blue ink, appearing to be 'R. Balius Matas', written over a horizontal line.

Dr. Ramon Balius Matas
Esplugues de Llobregat, July 29, 2022

AIM: To evaluate the feasibility of employing augmented reality (AR) through smart glasses in out-of-hospital emergencies for video assistance and basic life support (BLS) training.

METHODS: Five studies were conducted, incorporating simulations in various settings. Participants underwent brief smart glasses training and were evaluated based on protocol adherence, performance, and user experience.

RESULTS: The findings indicated successful use of smart glasses for effective communication between bystanders and medical dispatchers, leading to improved performance during emergencies. AR interventions notably enhanced the understanding of protocol adherence, technique quality, and bystander performance in simulated out-of-hospital cardiac arrest scenarios.

CONCLUSIONS: Smart glasses demonstrated feasibility in out-of-hospital settings, facilitating effective information transfer, aiding in childbirth assistance, and contributing to BLS training. These results suggest the potential of smart glasses in improving emergency response and medical education.