Augmented reality (AR) in minimally invasive surgery (MIS) training: where are we now in Italy? The Italian Society of Endoscopic Surgery (SICE) ARMIS survey

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Accepted: 12 September 2022

Abstract

Minimally invasive surgery (MIS) is a widespread approach in general surgery. Computer guiding software, such as the augmented reality (AR), the virtual reality (VR) and mixed reality (MR), has been proposed to help surgeons during MIS. This study aims to report these technologies' current knowledge and diffusion during surgical training in Italy. A web-based survey was developed under the aegis of the Italian Society of Endoscopic Surgery (SICE). Two hundred and seventeen medical doctors' answers were analyzed. Participants were surgeons (138, 63.6%) and residents in surgery (79, 36.4%). The mean knowledge of the role of the VR, AR and MR in surgery was 4.9 ± 2.4 (range 1–10). Most of the participants (122, 56.2%) did not have experience with any proposed technologies. However, although the lack of experience in this field, the answers about the functioning of the technologies were correct in most cases. Most of the participants answered that VR, AR and MR should be used more frequently for the teaching and training and during the clinical activity (170, 80.3%) and that such technologies would make a significant contribution, especially in training (183, 84.3%) and didactic (156, 71.9%). Finally, the main limitations to the diffusion of these technologies were the insufficient knowledge (182, 83.9%) and costs (175, 80.6%). Based on the present study, in Italy, the knowledge and dissemination of these technologies are still limited. Further studies are required to establish the usefulness of AR, VR and MR in surgical training.

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Keywords Minimally invasive surgery (MIS) · Augmented reality (AR) · Virtual reality (VR) · Mixed reality (MR) · Training · Survey

Introduction

Minimally invasive surgery (MIS) is a widely adopted approach in general surgery [1]. Compared to conventional open surgery techniques, this approach differs mainly in the interposition of a dedicated laparoscopic optic and instruments between the surgeon and the patient [1]. This situation creates several potential issues for the surgeon, including the loss of direct sense of touch. In addition, the MIS instrument replaces the force feedback by reducing or eliminating the surgeon's differentiation between soft and hard tissues and blood pulse sensation. Moreover, the loss of depth perception, as the optic is predominantly monocular, and the limited camera field of view do not allow to simultaneously monitor all anatomical structures and instrument movements [1].

To compensate for the lack of tactile sense, the depth of perception and a wide operative field, computer guiding softwares have been proposed to help surgeons [1]. The possibility to digitize and process preoperative data, retrieved, for example, from computed tomography (CT) scan or magnetic resonance imaging (MRI), allows creating of 3D models of the patient's anatomy, aiming to create computer guiding systems for intraoperative use [1].

The first system was named virtual reality (VR), and it was reported for the first time in 1989 by Jaron Lanier [2]. It refers to "a computer-generated representation of an environment that allows sensory interaction, thus giving the impression of actually being present", therefore, to a purely virtual scenario [2]. The evolution of this system is the augmented virtuality and consists of a virtual environment controlled by real information [1]. Another guiding system is augmented reality (AR), which consists of virtual information on real patients' images [1, 3–5]. Compared to the VR, the AR superimposes artificial images for the real endoscopic image augmentation in the MIS scenario, such as vessels or tumors, facilitating their identification or facilitating and guiding instruments movement [1, 3–5]. A further system proposed is the mixed reality (MR) [6, 7]. This was first defined by Milgram et al. in 1994 [6] as "*anywhere between the extreme of the virtuality continuum (VC) where the VC extends from the completely real through to the completely virtual environment with AR and augmented virtuality ranging in between*" [6, 7]. MR combines real and virtual scenarios, creating a new environment and interacting with real-time physical and digital objects [6, 7].

These concepts have been adopted in general surgery to create tools to train and guide surgeons intraoperatively [8–10].

The Italian Society of Endoscopic Surgery (SICE) and New Technologies is very interested in all scenarios concerning MIS and its new technologies and developed the present study to investigate and report the current knowledge and diffusion of AR, VR and MR during surgical training in Italy through a national survey.

Methods

This study was conducted according to the ethical guidelines for good research and practice published by the World Health Organization [11] and to the E-Surveys Checklist for Reporting Results of Internet (CHERRIES) [12].

The steering committee of the ARMIS study (A.B., A.S., G.R., E.B., F.A.) promoted, under the aegis of the SICE, a web-based survey to investigate the AR spreading during surgical training in Italy. The survey was dedicated to both surgical residents and attending surgeons.

A questionnaire was developed by the steering committee. Once a general agreement among the steering committee members concerning all questions was achieved, the electronic questionnaire was tested for its functionality and published online using Google Form (Google LLC, Mountain View, California, USA). The link to complete the questionnaire was sent to all SICE members by email and other potential participants by email, social media and personal invitation.

The questionnaire was divided into three sections (personal data, knowledge of technology and evaluation of the specific interest in the analyzed technology), including 15, 11 and 7 questions, respectively (Supplementary material). All answers were mandatory. The estimated mean time to complete the survey was fifteen minutes.

The questionnaire was available online on July 6, 2021, and a reminder was sent each month until December 31, 2021. In addition, the link was sent through the mailing list of SICE and personal invitations from the steering committee. Moreover, the link was available on the SICE website (https://siceitalia.com/area-medico/studi-sperimentali/study-augmented-reality), in the area dedicated to the scientific research that is proposed or endorsed by the Society.

Statistically analysis

Continuous variables were expressed as mean and standard deviation (SD), while categorical variables were expressed as frequencies and percentages. Data were stored in the Microsoft Excel program (Microsoft Corporation, Redmond, Washington, USA).

Results

Two hundred and seventeen medical doctors sent their complete responses to the questionnaire, and their answers were analyzed. Table 1 reports the results of the participants' data. Most of the participants were men (151, 69.6%) with a mean age of 38 ± 12.7 years, and most of them were attending surgeons (138, 63.6%), while the others were residents in surgery (79, 36.4%).

Most of the participants worked at Hospital Agency integrated with the University (89, 41%), Hospital Agency (76, 35%) and Hospital Agency integrated with the National Health System and Scientific Institutes of Hospitalization and Care (13, 6%). One hundred and fifty-seven participants were SICE members, and most of the participants practised general surgery and abdominal surgery (188, 86% and 158, 72.8%, respectively).

Table 2 reports results about knowledge of technology. The mean perceived knowledge of the VR, AR and MR role in surgery was 4.9 ± 2.4 out of a maximum score of 10. Figure 1 reports the distribution of the answers ranging from 1 to 10. Most of the participants (122, 56.2%) did not have experience with any proposed technologies. VR, AR and MR have been used primarily for training purposes (68, 31.3%), followed by didactic (6, 29%) and intraoperatively (27, 12.4%), even if most of the participants have never used these technologies (105, 48.4%). However, although most participants did not have any experience in this field, the questions to test their knowledge of these technologies were answered correctly in most cases (Table 2).

Table 3 reports the results of the evaluation of the specific interest in the analyzed technology. Most of the participants answered that VR, AR and MR should be used more frequently for the teaching and training in surgery and during the clinical activity (170, 80.3%) and that such technologies would make a significant contribution, especially in training (183, 84.3%) and didactic (156, 71.9%). According to the participants, the current mean relevance of VR, AR and MR in the teaching and the training and surgery was 4.4 ± 2.6 (range 1–10) and 4.1 ± 2.5 (range 1–10), respectively (Table 3). At the same time, the mean benefit in the teaching and the training and surgery was 8.3 ± 1.8 (range 1–10) and 8.1 ± 1.7 (range 3–10), respectively (Table 3). Figure 2 reports the distribution of the answers ranging from 1 to 10. Finally, according to most participants, the limits for the diffusion of these technologies were mainly insufficient knowledge (182, 83.9%) and costs (175, 80.6%).

Discussion

The present study investigated the knowledge and diffusion of VR, AR and MR technologies during surgical training in Italy. Based on the present analysis, these technologies in MIS are still poorly diffused and little-known tools. Few surgeons could experience this technology mainly for didactic and training, and most agree that currently, the relevance of these tools is low. However, its diffusion would translate into training and surgical activity benefits.

The first studies about this topic were published in the early 2000s. Since then, a great diffusion occurred in the last two decades, and more than half of the entire literature has been published since 2011, proving that technology is expanding worldwide [3].

VR during surgery confers several advantages to the surgeon, such as preoperative surgical planning and intraoperative navigation, easy and safe trocar placement to reduce iatrogenic injury and bleeding, and better recognition of anatomical variations. Moreover, multimodal imaging provides complementary insights before and during surgery, which are helpful at crucial moments in the surgeon's decision-making [7, 13, 14].

Anyway, VR, AR and MR, not only during the surgery but also for training simulators, are significant technological advances for surgeons [16]. Nowadays, it is inappropriate for surgical trainees to practice basic laparoscopic skills directly in the operating room, increasing potential risks for patients. The great variety of simulation methods available allows to improve the surgical skills in a safe and controlled environment and therefore reduce the possible risks for the patients. For this reason, physical box trainers, video trainers and VR simulations have gained importance in surgical training [15, 16].

In 2016, Alaker et al. in their meta-analysis reported the utility of VR as a training tool and compared it with no training, box trainer and video trainers [15]. In comparison with no training, they found that VR had better results in terms of time to complete tasks [15]. Moreover, when scores, distance moved, path lengths, motion-in-depth, the economy of movement and accuracy were evaluated, and VR was superior to no training [15]. However, when VR compared to box trainers, statistically significant differences in the time to complete the task were not observed even if the VR showed a shorter time [15]. Eventually, a statistically significant shorter time favoring VR was obtained when VR compared to video trainers alone and with box and video trainers combined [15].

In 2021, Jin et al. published a further meta-analysis to evaluate the utility of VR in the learning curve of laparoscopic training, comparing it with no training, box trainers, video trainers and traditional trainers [16]. In comparison with no training, VR showed better statistically significant results in both time and scores [16]. However, when VR was compared with box trainers, a statistically significant difference was not achieved, and box trainers obtained better results in terms of time and scores [16]. On the other

Table 1 Results from questionnaire Sect. 1

Gender ratio, Women (%): Men (%)	66 (30.4): 151 (69.6)
Mean age ± SD, years (range)	38 ± 12.7 (25—74)
Residents, *n* (%)	79 (36.4)
Surgeons, *n* (%)	138 (63.6)
Italian region of practice, *n* (%)	
- Abruzzo	4 (1.8)
- Basilicata	2 (0.9)
- Calabria	4 (1.8)
- Campania	40 (18.4)
- Emilia-Romagna	24 (11)
- Friuli-Venezia Giulia	2 (0.9)
- Lazio	47 (21.7)
- Liguria	1 (0.5)
- Lombardia	28 (12.9)
- Marche	9 (4.1)
- Molise	–
- Piemonte	13 (6)
- Puglia	3 (1.4)
- Sardegna	4 (1.8)
- Sicilia	10 (4.6)
- Toscana	5 (2.3)
- Trentino-Alto Adige	4 (1.8)
- Umbria	2 (0.9)
- Valle d'Aosta	–
- Veneto	13 (6)
- Other countries	2 (0.9)
Type of hospital where the profession is practised, *n* (%)	
- Public hospital	76 (35)
- Directly managed hospital	4 (1.8)
- Public hospital of the National Health System	13 (6)
- Public University hospital affiliated with the National Health System	89 (41)
- Private University hospital affiliated with the National Health System	3 (1.4)
- Scientific institute affiliated with the National Health System (IRCCS)	13 (6)
- Hospital classified or assimilated	2 (0.9)
- Private Institution	–
- Qualified Institution local health company (ASL)	6 (2.8)
- Research Institute	1 (0.5)
- Private hospital affiliated with the National Health System	9 (4.1)
- Private hospital not affiliated with the National Health System	–
- Other	1 (0.5)
Working position, n (%)	
- Attending surgeon	75 (34.6)
- Medical doctor with freelance contract	2 (0.9)
- Freelance medical doctor	6 (2.8)
- University researcher	11 (5)
- Associate professor	10 (4.6)
- Ordinary professor	5 (2.3)
- Chief of Surgical Unit (UOC) / (UOS)	27 (12.4)
- Resident	79 (36.4)
- Other	2 (0.9)
Italian Society of Endoscopic Surgery (SICE) member, *n* (%)	157 (72.4)

Table 1 (continued)

Type of surgical activity performed (more than one activity), n (%)	
- General surgery	188 (86.6)
- Abdominal surgery	158 (72.8)
- Abdominal wall surgery	130 (59.9)
- Digestive surgery	126 (58)
- Colorectal surgery	154 (71)
- Bariatric surgery	49 (22.6)
- Emergency surgery	106 (48.8)
- Endocrine surgery	51 (23.5)
- Hepatobiliary-pancreatic surgery	69 (31.8)
- Transplant surgery	17 (7.8)
- Breast surgery	13 (6)
- Endoscopy	4 (1.8)
Number of surgical procedures performed as the first operator on average in one year, n (%)	
- 0–10	37 (17)
- 11–50	72 (33.2)
- 51–100	36 (16.6)
- 101–300	50 (23)
- > 300	22 (10.1)
Number of surgical procedures not performed as the first operator on average in one year, n (%)	
- 0–10	9 (4.1)
- 11–50	42 (19.4)
- 51–100	59 (27.2)
- 101–300	88 (40.6)
- > 300	19 (8.8)

hand, differences were not observed also comparing VR with video trainers [16]. Lastly, compared to traditional trainers, VR showed a steeper learning curve and shorter total time and statistically significant better scores in the meta-analysis [16]. In our opinion, the discrepancy of these results demonstrates that although the technology is expanding, further studies are needed to clarify its usefulness.

As retrieved from the present analysis, the reason for the poor spread of these technologies in Italy may be the costs. Anyway, if, on the one hand, VR, AR and MR have a high initial cost, on the other hand, it could allow for considerable savings in clinical practice, reducing operative time and postoperative complications when non-expert surgeons operate, as reported in the literature [17]. However, in our opinion, the lack of tutors who are familiar with these technologies may be listed among the causes of poor diffusion.

The present analysis could be a starting point for VR spread in the Italian residency programs, considering its contribution to surgeons' training, the possibility of reducing the learning curve, especially in advanced MIS procedures, and the possibility of continuing the learning curve also in unpredictable situations such as a pandemic. Furthermore, the contribution of the Scientific Societies and dedicated government programs could bridge the economic gap.

To the best of our knowledge, this is the first study reporting the knowledge and diffusion of these technologies during surgical training in Italy. The main limitations of the present study are the small number of participants and the fact that the analysis was limited to one country, existing the possibility of different scenarios in other countries.

Conclusions

Based on the present study, the knowledge and dissemination of AR, VR and MR technologies in Italy are still limited. Surgical and medical tutors with a well-structured theoretical and practical knowledge of these technologies should actively contribute to their dissemination. Further studies are required to establish the usefulness of VR, AR and MR in surgical teaching and training through the analysis of measurable outcomes.

Table 2 Results from questionnaire Sect. 2

Knowledge concerning the role of VR, AR, and MR in surgery, mean ± SD, (range) (Fig. 1)	4.9 ± 2.4 (1–10)
Experience with n (%)	
- VR	31 (14.3)
- AR	19 (8.8)
- MR	3 (1.4)
- VR, AR	24 (11)
- VR, MR	2 (0.9)
- AR, MR	4 (1.8)
- VR, AR, MR	12 (5.5)
- None	122 (56.2)
The area where you used VR, AR or MR, n (%)	
- Didactic	63 (29)
- Training	68 (31.3)
- Planning	25 (11.5)
- Preoperatively	24 (11)
- Intraoperatively	27 (12.4)
- Never	105 (48.4)
VR allows to interact, n (%)	
- Mainly with the real world	8 (3.7)
- With both, real and digital world	35 (16.1)
- Exclusively with the digital world *	174 (80.2)
AR allows to interact, n (%)	
- Mainly with the real world *	153 (70.5)
- With both, real and digital world	53 (24.4)
- Exclusively with the digital world	11 (5.1)
MR allows to interact, n (%)	
- Mainly with the real world	17 (7.8)
- With both, real and digital world *	196 (90.3)
- Exclusively with the digital world	4 (1.8)
Which of the following VR devices are you familiar with? n (%)	
- Oculus Quest	47 (21.7)
- Google Glass	74 (34.1)
- Smartphones	47 (21.7)
- HTC Vive	14 (6.5)
- Tablets	73 (33.6)
- Epson Moverio	1 (0.5)
- Valve Index	7 (3.2)
- Microsoft HoloLens	17 (7.8)
- None	62 (28.6)
Which of the following AR devices are you familiar with? n (%)	
- Oculus Quest	24 (11.1)
- Google Glass	87 (40.1)
- Smartphones	50 (23)
- HTC Vive	2 (0.9)
- Tablets	42 (19.4)
- Epson Moverio	5 (2.3)
- Valve Index	1 (0.5)
- Microsoft HoloLens	19 (8.8)
- None	85 (39.2)

VR virtual reality, *AR* augmented reality, *MR* mixed reality, *SD* standard deviation *Correct answer

Fig. 1 Knowledge concerning the role of virtual reality, augmented reality and mixed reality in surgery

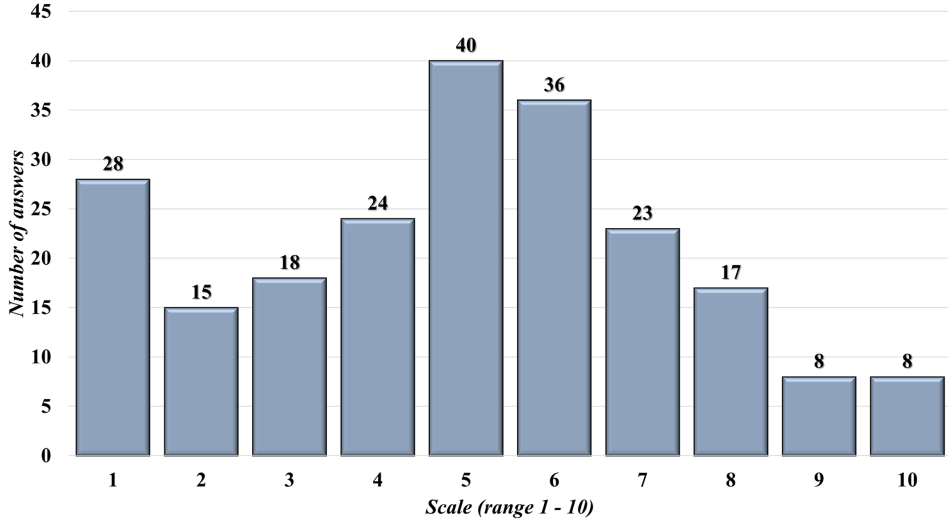

Table 3 Results from questionnaire Sect. 3

VR, AR and MR should be used more frequently in the context of, n (%)	
- Teaching and training in surgery	46 (21.2)
- Clinical surgical activity	1 (0.5)
- In both cases	170 (78.3)
- In none of the cases	
Area in which VR, AR and MR make a significant contribution, n (%)	
- Didactic	156 (71.9)
- Training	183 (84.3)
- Planning	127 (58.5)
- Preoperatively	112 (51.6)
- Intraoperatively	115 (53)
Relevance that VR, AR and MR currently have in the field of teaching and training in surgery, mean ± SD, (range) (Fig. 2)	4.4 ± 2.6 (1–10)
Relevance that VR, AR and MR currently have in the context of clinical surgical activity, mean ± SD, (range) (Fig. 2)	4.1 ± 2.5 (1–10)
Do you think that teaching and surgical training would benefit from a greater diffusion and use of VR, AR and MR? mean ± SD, (range) (Fig. 2)	8.3 ± 1.8 (1–10)
Do you think that the clinical surgical activity would benefit from a greater diffusion and use of VR, AR and MR? mean ± SD, (range) (Fig. 2)	8.1 ± 1.7 (3–10)
Limits to the greater diffusion and use of VR, RA and MR in surgery, n (%)	
- Insufficient knowledge	182 (83.9)
- Excessive complexity	44 (20.3)
- Costs	175 (80.6)
- Insufficient benefit for patients	13 (6)
- Insufficient benefit for surgeons' training and practice	7 (3.2)
- Other	11 (5.1)

VR virtual reality, *AR* augmented reality, *MR* mixed reality, *SD* standard deviation

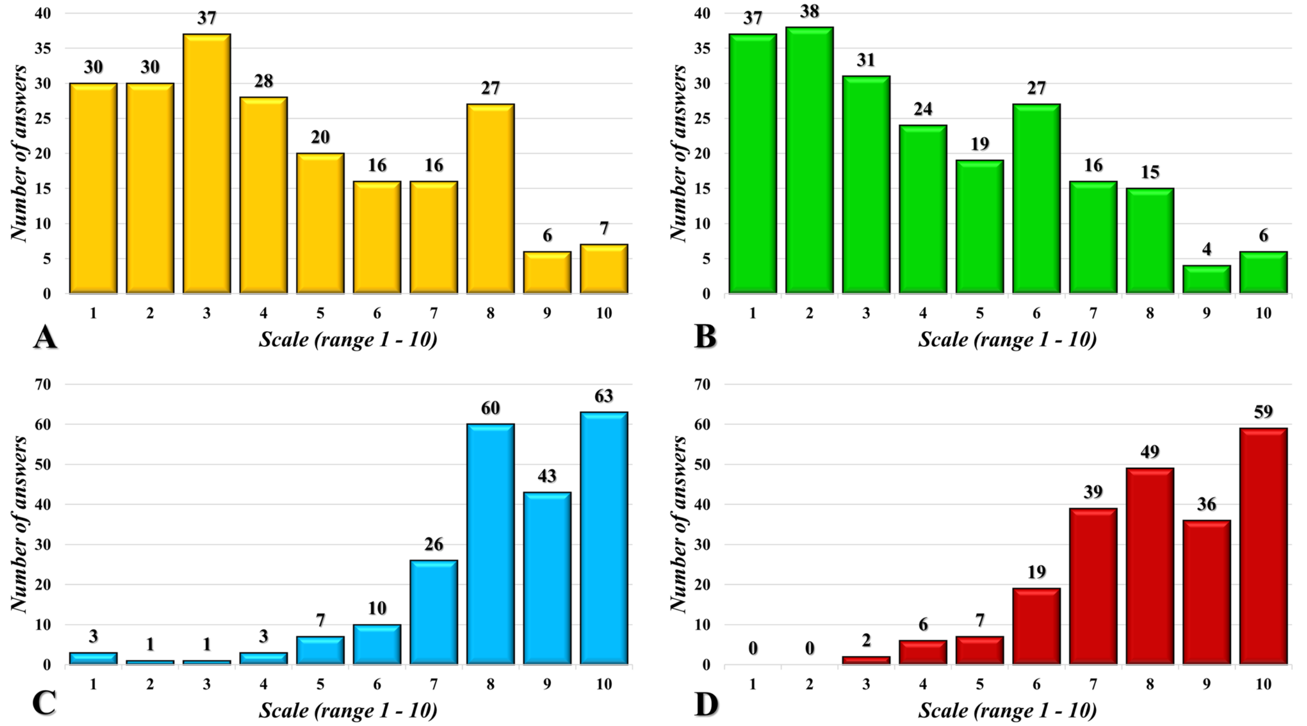

Fig. 2 **A** Relevance that virtual reality (VR), augmented reality (AR) and mixed (MR) currently have in the field of teaching and training in surgery. **B** Relevance that VR, AR and MR currently have in the context of clinical surgery. **C** Answer to: Do you think that teaching and surgical training would benefit from a greater diffusion and use of VR, AR and MR? **D** Answer to: Do you think that the clinical surgical activity would benefit from a greater diffusion and use of VR, AR and MR?

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s13304-022-01383-6.

Acknowledgements Collaborators to be indexed: ARMIS (Augmented Reality in Minimally Invasive Surgery) Collaborative Group*.

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Siragusa, Carmen Sorrentino, Giuseppe Surfaro, Ernesto Tartaglia, Beatrice Torre, Andrea Tufo, Matteo Uccelli, Alessandro Ussia, Samuele Vaccari, Marina Valente, Sara Vertaldi, Alessandro Vitali, Luca Zaccherini, Luigi Zorcolo, Noemi Zorzetti.

Author contributions AB, AS, EB, MP, MO, GS, MG and FA did study conception and design, acquisition of data, analysis, and interpretation of data, drafting of manuscript, critical revision of manuscript, and final approval.

Funding The authors received no financial support for the research, authorship, and/or publication of this article.

Availability of data and material All raw data are available if required under direct request of the corresponding author of the article.

Code availability (software application or custom code) Not applicable.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. A formal approval by the Ethics Committee is not required for survey studies in Italy.

Consent to participate Informed consent from all participants was obtained.

Consent for publication All authors approved the publication of the manuscript in the Journal.

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