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Artificial Intelligence Surgery

Review

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The potential of artificial intelligence as an equalizer of gender disparity in surgical training and education

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Abstract

The aim of this work is to offer a panoramic view on how artificial intelligence (AI) can help to break down gender disparity in enrollment and training of women in surgery. Nowadays, many visible and concealed obstacles still exist for women who pursue a surgical career. Impediments due to gender disparity prevent women from choosing surgical specialties. Furthermore, female surgical trainees have to face many difficulties during their training, such as inequity during the residency selection process, sexual harassment, discrimination in pregnancy experience and parental leave, and work-life balance problems. AI has been successfully employed for several applications in surgery to improve patient management, implement the decision-making process, and support training. AI could represent an effective way to overcome barriers related to gender disparity and overcome the obstacles women face during surgical education and training. Virtual and augmented reality, remote mentoring, and simulators could help female surgeons deal with disparities during their training and could positively impact the choice of women when pursuing a surgical career.

Keywords: Women in surgery, artificial intelligence, surgical training, gender discrimination, choose surgery

INTRODUCTION

Over the last decades, female enrollment in medical schools has steadily increased. However, this growth did not lead to a proportional rise in females studying surgical specialties, which seems unable to attract and retain many young female doctors[1]. Manifest and occult barriers still prevent young women from enrolment, promotion, training opportunities, and career progression in surgical departments[1-5].

Several factors are responsible for the limitations in recruitment and advancement of young female doctors in surgical specialties, such as social and cultural barriers, gender discrimination and harassment, surgical lifestyle, and the lack of mentors and same-gender role models[6]. The main perceived obstacles in achieving a satisfying surgical career seem to be societal stereotypes, gender-biased mentality, and the lack of an adequate work-life balance[7,8].

Despite discrimination and obstacles, no significant differences were shown between males and females in learning surgical skills, among neither medical students nor surgical trainees[9-11]. However, gender disparity was observed in self-confidence, self-evaluation, and perception of competence achieved: female surgical trainees more often undervalue their abilities, especially their technical skills[10,12,13]. Independence, operative exposure, and faculty opinions of female residents' ability could be influenced by this attitude, constraining opportunities for female surgeons in training.

To break through the glass ceiling in training for women in surgery, many solutions have been proposed. An early education for students on gender discrimination, setting up formal and informal mechanisms for identifying and preventing inappropriate behavior, promoting flexible career and work patterns, and sponsoring female mentors and role models have been advocated as possible ways to reduce the gender gap in surgery. Although these suggestions seem beneficial, they have not been enacted, and significant results have not been achieved yet[14,15].

Artificial intelligence surgery (AIS) could play a role in facing the gender gap in training and education of surgical specialties. AIS studies how autonomously acting machines can understand, process, and perform interventional actions. Machine learning (ML), deep learning (DP), computer vision (CV), and natural language processing (NLP) are leading toward more autonomous actions in surgery, with diagnostic and therapeutic potential[16]. In this paper, we aim to analyze different applications of AIS for breaking down gender disparity in the enrollment and training of women in surgery.

MAIN TYPES OF DISCRIMINATION IN SURGICAL EDUCATION AND TRAINING

Barriers to the choice of a surgical career

Many studies have analyzed the reasons preventing women from choosing surgical specialties. The main deterrents for female doctors in pursuing a surgical career are the length of training, time to date or marry, time available to spend with family, finding a good time during residency to have a child, taking maternity leave during residency, and being too old after residency to have children[5].

Furthermore, the perception of gender-based discrimination, the presence of a glass ceiling, the opinion of surgery as a male-dominated field, inadequate flexibility during training, and a lack of mentors or female surgeons as role models were identified as other factors which dissuade women from choosing a surgical path[17].

Analyzing the main barriers to selecting surgery as a specialty for medical students from 75 countries, the Global Surgery Working Group identified difficult access to surgical training, long years of study, heavy workload, and the high costs of training as the main issues for students from low and low-middle income countries[18]. Moreover, this study revealed that female students from low and low-middle income countries were 40% less likely than their male colleagues to consider a surgical career when controlling for other factors[18].

Factors that can increase female doctors' interest in surgery have been the topics of different studies. Early exposure to surgical specialties during medical school, mentorship, and role models were identified as the factors which increase the likelihood that female doctors will pursue a surgical specialty[19-23]. Additional ways to encourage women's representation in surgical departments were flexible working patterns, shortened training time, improved sense of belonging, and better work-life balance[24-27].

Exposure to other women who have pursued a surgical career was considered one of the most inspirational reasons to induce young women to follow a surgical career[28]. Furthermore, suggestions and mentoring by fellow surgical residents were shown to be even more effective than mentorship by a faculty member[19]. Mentorship and role models were recognized as one of the principal factors in supporting interest in surgery[18,21,23,28].

Surgical training

During surgical training, women had to face several obstacles, such as gender disparity, inequity during the surgical residency application process and interview, imbalance in the bestowment of awards, sexual harassment, and discrimination in pregnancy experience and parental leave.

In pursuing a surgical career, female doctors had to deal with gender discrimination during the procedure of residency application, including recommendation letters[29-33], interviews[34-38], and fellowship applications[39,40]. Furthermore, female applicants required superior letters of recommendation to be given the same opportunity as male candidates[30]. However, when standardized letters of recommendation were requested, these disparities were not present[31].

During residency interviews, applicants frequently received questions about personal matters which were unrelated to medical school performance. Female respondents more frequently experienced a potentially illegal question compared to male applicants[36]. Women were recurrently asked about marital status, family planning, and maternity plans[37].

During surgical training, women experienced disparities in operative autonomy and evaluation, and interesting differences were also observed in self-evaluation[11,41-48]. A significant difference between male and female residents' operative autonomy was observed during surgical training programs. Even though a gender disparity in residents' performance was not demonstrated, women tended to underestimate their abilities compared to faculty assessment[46-48].

Female residents were revealed to be more likely to experience several other kinds of discrimination during their training, compared to their male colleagues. Female trainees more commonly experience stereotyping and discrimination, such as being mistaken for non-physicians, being subject to different standards of evaluation, and being victims of harassment[49-51].

During training, significant discrimination was also reported with pregnancy experience and family planning. Women were less likely to have children during surgical residency because of stigma, fear of modification of their fellowship program, and perception of missing out on a job opportunity[20,52-55]. In many countries, there is a lack of a formal policy for maternity leave or a maternity support program during residency. This deficiency is another issue reported as an obstacle in pursuing a surgical career[55,56].

All these barriers and discrimination experienced during surgical training led to a higher rate of burnout, depression, and suicidal thoughts among female surgical residents compared to male trainees[50,57-59]. Thus, female trainees were observed to be more likely to leave surgical residency[60-62].

AIS IN SURGICAL EDUCATION AND TRAINING FOR WOMEN

AI is the study of how computers can understand, process, and act autonomously in the real world[63]. In AIS, machines perform interventional actions[16].

ML is a field of AI in which computers reproduce the acts of learning and solving problems, improving their performance by learning from data[16,63]. AI models examine high volumes of data, and then offer accurate predictions for upcoming events based on the statistical analysis of previous associations, and they constantly improve with new data. Neural networks can develop over time thanks to incremental learning processes, going beyond standard software[16,63].

Natural language processing (NLP) is the interaction of AI and linguistics. NLP has advanced from essential approaches (e.g., word to word) through an evolved process of coding words, sentences, and contexts[64].

Thanks to the aforementioned research, AI has already been employed in several fields in surgery, especially to optimize patient management, support training, and improve surgical skills.

With AI, augmented reality offers enhanced vision by superimposing a digital image over the user's view, while virtual reality allows interacting with a digitally created setting[65]. Surgical simulation based on virtual reality (VR) allows training and practice in a safe setting so residents can learn from their errors without harming patients[66]. In the last few years, several surgical simulators for different surgical specialties, procedures, and variants have been designed. The simpler ones are low-fidelity simulators that teach basic surgical procedures. For example, the MIST-VR system was developed to teach basic laparoscopic skills, suturing, and knot-tying[67]. High-fidelity VR systems include the Lap Mentor which incorporates over 65 cases in the fields of general surgery, gynecology, urology, and bariatric surgery[68,69]. The potential of VR for training and monitoring basic laparoscopic skills and full laparoscopic procedures is well recognized[70]. The routine use of surgical simulations can reduce operative times and complication rates, improving patient outcomes[66].

VR simulations offer real-time feedback to users about their performance within the simulation. They can evaluate time to complete a task, errors made during surgery, and the surgeon's economy of movements[71], providing a method for skill evaluation that is objective and quantitative, not influenced by the gender of the operator. Although VR simulations are burdened by some disadvantages, such as high costs, lack of force feedback, and the limited realism of some simulation models[72], as VR technology advances, simulators are getting more cost-effective and more able to reproduce human anatomy. A relatively new development in training simulators is robot-assisted laparoscopic surgery simulators (RAS). Studies on Da Vinci simulators suggest that they reduce the console training time, although RAS simulators are burdened by high costs and a lack of high fidelity surgical simulations[73]. However, the Da Vinci Skills simulator could

be a feasible tool for the evaluation of RAS skills and credentialing of RAS surgeons, allowing them to obtain an objective assessment of technical skills that are not prejudiced by the surgeon's gender[74]. The development of simulators for RAS is only beginning, and technological improvement may permit the development of cheaper and better systems in the future.

AI may have further employment in supporting female surgeon training and facilitating their surgical career, by facing gender barriers and disparity.

AI is useful even during the selection process of surgical residency programs. Sarraf *et al.* demonstrated that AI with NLP can identify linguistic differences and gender disparity in letters of recommendation for general surgery residency applicants[75]. AI could detect implicit biases in female applicants' selection and thus avoid them, in order to obtain equal resident selection.

During surgical training, the importance of one-on-one mentoring was demonstrated for female trainees, who were shown to be particularly receptive to this kind of approach[10]. The integration of AI and robotic surgery could be employed to provide remote surgical mentoring and training to surgical residents, transferring surgical skills and knowledge. Telerobotic surgery has firmly demonstrated the feasibility and clinical safety of remote telementoring in surgery[76-78]. Telementoring has been tested as a training method for several laparoscopic procedures, such as cholecystectomy[79], adrenalectomy[80], colon surgery[81], and bariatric surgery[82]. However, more studies are needed to confirm the same effectiveness of telementoring as an educational intervention compared to on-site mentoring[83]. However, telementoring has already been successfully used in surgical training in rural areas of Canada[84]. Moreover, it may have a role in extending the possibility of training surgical residents in low-and middle-income countries, reducing the significant limitations due to travelling[85].

Promising perspectives also seem to be offered by robotic telementoring. For instance, it has been shown that telerobotic-assisted colorectal surgery is feasible and safe for patients, and it is an effective tool for supporting surgeons during the learning curve[86]. Similar evidence was provided in neurosurgery by Mendez *et al.*, who completed six long-distance robotic-assisted telementoring neurosurgical procedures[87]. Thus, robotic-assisted telementoring could also potentially facilitate the teaching of advanced surgical skills worldwide.

For female trainees, telementoring could also allow communicating remotely with same-sex role models and obtaining mentoring and counselling, even in centers with few female surgeons who can fit this role. This approach could not only help women to improve their surgical technical skills but also help raise awareness of gender issues and how to deal with them during surgical training[88].

Similar to how virtual reality and robotic surgery can be used to train surgeons at work, this solution may be used for trainees on maternity leave to continue their training and avoid losing their technical skills. Cost, size of the machine, and limited functionality are problematic, which might be eliminated or reduced by developing new technologies. Therefore, the possibility provided by AIS to train anywhere and anytime with virtual reality and simulators in surgery could significantly contribute to ameliorating female surgeons' work–life balance issues[89].

The positive effect of AI on training, education, and remote mentoring could favorably impact the choice of young women to pursue a surgical career. AI could help female surgical trainees in facing many of the above-mentioned obstacles, so they would not be forced to choose between their careers and personal life.

Furthermore, all these facilities could contribute to reducing the rate of female surgeons who abandon their training and profession because of difficulties due to gender disparity and discrimination[90].

However, there are some open issues in the everyday application of AI in training and education in surgery. Potential disadvantages of routine employment of AI in surgical training are high costs and technical requirements[91]. Obstacles to the implementation of telementoring include poor video signal due to bandwidth or latency, loss of transmission, and poor audio quality[92]. Furthermore, hospital licensing and credentialing might be required, creating an additional limitation to the introduction of AI in surgical training[83].

Furthermore, AI is based on enormous datasets, so the management and cybersecurity of personal data is a critical issue for the application of AI[93]. Finally, there are ethical problems related to AI application in surgical training[93]. For instance, there might be an ethical issue related to the responsibility of the surgeon who operates and teaches from a distant location, possibly in another country, thanks to telementoring[77].

CONCLUSION

AIS permits remote training and telementoring and could improve female surgeons' education worldwide. AI could contribute to breaking down gender disparity in surgical training, and, consequently, it could encourage women to choose a surgical career. Many surgical tools have been created and tested on male surgeons (especially laparoscopic instruments and staplers)[94-96]; future studies should develop instruments considering gender differences. The development of systematic AI-based training and education programs could encourage women to choose a surgical career and help break down gender disparity during surgical training.

DECLARATIONS

Authors' contributions

Study concept and design: Ferrari L, Mari V
Drafting of manuscript: Mari V
Critical revision: Ferrari L, Spolverato G

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All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

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