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Editorial

Percutaneous image-guided surgery

Mariano E. Giménez^{1,2,3,4,*}

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Background

The origins of surgical interventions on humans are older than the development of clinical medicine. The corporal barrier was broken long before ancient minds became aware of the profound wisdom of not breaching it. To eliminate what was clearly anomalous, such as a tumor, a growth, a festering wound, a broken limb, or a persistently painful tooth, involved a swift medical decision that offered a quick solution to a problem and did not require profound knowledge or special care.

Surgery was slow to lose its characterization as a minor, subsidiary technique, and its status as a craft. Ambroise Paré (1510–1590) gave surgery a more appropriate technical base. Among other therapeutic measures, he stopped burning wounds to improve their condition. As far as surgery's path to professionalization was concerned, Paré could not have been better placed. He came from a family of barbers, and his work prompted the final break of surgery away from their trade. Surgery's gradual transformation into a medical specialization rapidly accelerated in the second half of the twentieth century, due to technological developments that allowed for constant improvements in the diagnosis and treatment of various pathologies.

As Richard Satava—a contemporary surgeon who specializes in the application of technology to surgery—argues, “The evolution of surgery through the centuries can be understood as passing through the ages of anatomy and physiology, anesthesia, antibiotics and minimally invasive surgery (MIS). The fifth, and (according to Satava) final stage, might be the development of robotic and computer controlled surgery.”¹

This article poses some questions and reflections about the image-guided surgery (IGS) in the midst of this technological whirlwind. I shall attempt to explain my vision about the path being followed by surgery, knowing full well that there will be as many visions as people addressing the issue. “In tomorrow's world,” wrote Lain Entralgo, “What will happen with surgery?”

Two utopian visions exist in the medical profession in answer to this question: the first predicts that preventive medicine and pharmaceuticals will make such progress that they will stop disease from arising in the first place, or at least from developing into a “surgical stage”; the second envisions such a degree of refinement in surgical techniques that surgery will become not only a valid means of curing disease or creating a better functional state than morbidity, but that it will also improve chances of staying healthy. In other words, we are looking at the disappearance or the transfiguration of surgery.

Between these two utopias, disappearance and transfiguration, exists what I believe to be a third path, characterized by profound transformation. This implies a transition from an essentially extirpating and mutilating surgery to a surgery that at times works to restore the original physiological balance and at other times works to create a new, healthier, and more harmonious functionality which is, after all, also more humane.²

What Is Then Percutaneous IGS?

Percutaneous IGS are procedures that are performed through the skin by minimal incision, guided by images and involve artificially intelligent (AI), robotic, data-driven, mixed reality, navigation systems and advances in image quality, image fusion and target location. These developments will also require surgeons (or whoever performs these techniques through the skin), to acquire various non-technical skills, centered mainly on teamwork and the exercise of new leadership styles.

In this way, we can say that IGS is the evolution of MIS. At the end of the last century, MIS allowed us to add something fundamental after diagnosis and before treatment: The possibility of “choosing the tool.” Before this, we only had open surgery, and with the arrival of MIS (laparoscopy, interventional radiology, and therapeutic endoscopy) we were able to choose what was best treatment for our patient.

¹General and Minimally Invasive Surgery, University of Buenos Aires, Buenos Aires, Argentina

²Percutaneous Surgery, Institute for Advanced Studies, University of Strasbourg, Strasbourg, France

³Percutaneous Surgery, IHU-IRCAD, Strasbourg, France

⁴DAICIM Foundation, Buenos Aires, Argentina

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* Corresponding author. DAICIM Foundation, Arenales 1640 1A, Buenos Aires C1061AAT, Argentina.

E-mail address: marianoegimenez@gmail.com (M.E. Giménez). ORCID: <https://orcid.org/0000-0002-1495-2956>

Now with the new technologies, we can do much more.

We propose that today you can and should perform 8 steps listed in Table 1.

High quality images

In recent years we have witnessed a significant increase in the use of high quality images in percutaneous surgery (improved image quality, image fusion, mixed reality, and navigation systems). This allows a combination of image-guided procedures, making them safer and less invasive by refining existing techniques.

To this end, we are seeing the construction of so-called hybrid operating rooms (Fig. 1).

These operating rooms are equipped with advanced medical imaging devices such as angiographs, as well as computed tomography (CT) and magnetic resonance imaging (MRI) scanners. Imagenology has been a standard tool in the operating room for a long time in the form of mobile C-arms, ultrasound, and endoscopy. However, new minimally invasive procedures are also now using image acquisition techniques to allow visualization of smaller parts of the body, rendering it “transparent.”³

Image fusion technology and augmented reality, which allows for the combination and overlap of intraoperative and postop-

erative images (MRI, CT, or positron emission tomography [PET] scans) as well as three-dimensional reconstruction, makes surgery safer and provides a more accurate guide as to where to puncture or cut (Fig. 2).

These are the ways in which true IGS will allow us to perform more precise, less aggressive procedures, causing less functional disruption and improving postoperative quality of life. Technology is not only “nice” or the latest trend in a marketing strategy, it makes operations safer for patients and will increasingly have an impact on surgical results.

Artificial intelligence

The near future of IGS will be the use of AI, which is defined as intelligence shown by machines. In computing, an ideal “intelligent” machine is understood to be a flexible rational agent that detects its surroundings and takes actions to maximize its chances of success in achieving a goal.⁴ The term AI is commonly used when a machine imitates cognitive functions that humans associate with other human minds, such as learning and solving problems. Thus some new computers are described as cognitive or AI computers. For example, there is Watson, IBM’s new cognitive computer, which is a type of AI expert system. Watson, named after IBM’s first president, can store more medical information than any individual human being, and can give answers to the natural language of surgeons in a matter of seconds. These AI machines will become intelligent surgery assistants.

Table 1 Actions on a Surgical Patient in the Era of Image-Guided Surgery

Step	Action
1. Diagnosis	a) HQ images (MRI – CT) b) Radiomics
2. Choosing a tool	a) Open, laparoscopic, endoscopic, percutaneous or combination b) Specific tool
3. Planning	a) Immersive technologies
4. Location of target	a) Image fusion b) Surgeomics
5. Navigation systems	a) Optical b) Electromagnetic c) Robotic
6. Treatment	a) Specific b) Robotic c) Mixed reality (dynamic augmented reality)
7. Immediately control of results	a) Image fusion b) MRI, elastography c) Delta radiomics
8. Follow-up	a) Specific b) Delta radiomics

HQ, high quality; MRI, magnetic resonance imaging; CT, computed tomography.

Fig. 1. Hybrid operating room at the IHU (University Hospital Institute), Strasbourg, France.

Fig. 2. (A) Ultrasound and computed tomography image fusion. (B) Augmented reality fusion on a robotic liver surgery. The tumor is observed in color and the intrahepatic vessels in relation to it.

Data-driven medicine

Another characteristic of IGS's future path will be data-driven medicine, which means data-based decision management. It goes beyond the concept of evidence-based medicine by changing the question from, "What data do we need?" to "How do we use this data to drive decision-making?"

Evidence-based decisions are normally undertaken to obtain competitive advantage. A study carried out by the Center for Digital Business at MIT (Massachusetts Institute of Technology) found that organizations driven by data-based decision making were 4% more productive and 6% more profitable.

However, integrating massive amounts of information from different areas (a common occurrence in medicine these days) and combining them to obtain actionable data in real time (necessary in surgery) can be very complex, and errors made in the process may cause serious problems. For this reason, the use of data in decision making (data-driven decision making) in conjunction with AI and robotic technologies may lead to a reduction in the number of problems encountered.

How Can We Get Ready for the Percutaneous IGS?

The traditional idea that "surgeons operate and the other specializations diagnose" no longer holds.⁵ Over the second half of last century, increased technological innovation has led to the development of new ideas, methods, and equipment (MIS). As a consequence, the boundaries between medical specializations, as Pellegrini has argued, have begun to blur. The notion of distinct medical departments (Surgery, Clinical Medicine, Radiology, etc.) is a structure that fit nineteenth century requirements, but it is unproductive in relation to the needs of the twenty-first century. The concept of multidisciplinary teams has been developed in order to correct this. Far from solving the problem, the development of these teams has shown the increased need to spend time with those who treat the same conditions regardless of our background. An hour a week is not enough; we need to be in contact on a full-time basis.

The traditional idea of meeting and working as a group in terms of "who we are," following the departmental logic, is shifting toward the idea of teams that work together on the basis of "what and who we treat." Centuries of egocentric behavior are being pushed aside in favor of true teamwork focused on patients and their problems.

Nonetheless, implementing the changes associated with these innovations often presents a difficult challenge for doctors and other health professionals, given the power structures they work in and the privileges they wish to maintain. Moreover, the same society that used to demand quality and safety in daily medical practice, now additionally requires keeping costs down while still obtaining good results. Not even the best surgeon can meet these four requirements working alone. This is why teamwork working under the guidance of modern leadership is necessary. By modern leadership I do not mean the traditional authoritarian leader, but a leader who will foster exceptional communication, mutual respect and support, and who will develop the direct means to fulfill our mission, which is none other than improving the health of our patients.

Many surgeons think that they work as a team when they actually only work in a group. In a work group, members have similar training and do the same type of work without complementing each other. In these groups, each person has individual responsibility. On the other hand, in high-performance teams

every team member is an expert in a specific area and is jointly responsible for the work done. This requires the establishment of common performance standards and the need for coordination. This is why cohesion is fundamental in teams, as is close collaboration among members.

Many studies⁶ have shown that failure to work as a team increases costs and complications in the operating room. In contrast, good teamwork produces better technical results. Additionally, respect for and the pursuit of team diversity (which in the past was taken as an obstacle) is inescapable. Work teams nowadays must foster and encourage differences among team members. The more multifaceted professionals are, the greater the capability of the team to achieve success.

Diversity facilitates innovation. If we all think the same and behave in the same way, we may well find ourselves in our comfort zone, but we are unlikely to innovate. In this line of reasoning, innovation is understood as the necessary foundation on which to create and adopt new technologies, which as we have seen are at the center of surgery's future. At the end of the day, although technology will dominate surgery in the future, whether we surgeons are able to adapt to and make the most of the changes or find ourselves gradually nudged out of the picture will depend on how we position ourselves in relation to the profession itself and its surrounding context. As always, opportunities do not present themselves from the outside, but emerge from within.

Conclusion

We are facing the change of an era, rather than an era of change.

As J. Marescaux suggests,³ the concept of general surgeon will become increasingly obsolete, to be replaced by the minimally invasive surgeon and complement now with image-guided surgeon. On the other hand, we are facing continuous technological advancement, sometimes accompanied by pressure from companies. We must work together to optimize results, accepting and adapting what is beneficial and leaving aside what doesn't represent true progress. What must not change is our perception. We have gone from thinking that a good surgeon was the one who made a large incision to thinking that it was the one who made smallest one. We come from a past filled with an abundance of great teachers and now it seems there is no one to lead us. None of this is true. The size of a wound does not make a good surgeon, and there are leaders, but we must seek them out because they are not going to come and knock on our doors.

The generational change that we observe and which terrifies us at times is actually an opportunity and is fundamental in order to assimilate and channel technological progress to the benefit of our patients. The young people who join our teams contribute to the building of a less formal vision, in which respect for professional values replaces a certain authoritarianism. They teach us older surgeons, as do social networks, the concept of shared information as the basis for participation. But the leadership of these teams is in our hands as senior professionals. Let's not say then that there is nothing we can do, because the future is in our hands. I agree with Giménez² when he says that the future of humanity lies not with children but with adults.

Children and young people must work and coexist with adults, and are transformed by adults as they interact with them. This is a huge responsibility. Today's adults—what we do, what we choose, what we think—are the future of humanity.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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E-mail: sgisci@sgiw.org
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