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Editorial

Engineering-Aided Inventive Surgery

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Abstract: This Editorial presents a new Special Issue dedicated to some old and new interdisciplinary areas of cooperation between engineering and surgery. The first two sections offer some food for thought, in terms of a brief introductory and general review of the past, present, future and visionary perspectives of the synergy between engineering and surgery. The last section presents a very short and reasoned review of the contributions that have been included in the present Special Issue. Given the vastness of the topic that this Special Issue deals with, we hope that our effort may have offered a stimulus, albeit small, to the development of cooperation between engineering and surgery.

Keywords: engineering; surgery; interdisciplinarity

1. Introduction

For centuries, humankind has been dreaming about how to save lives and pursue immortality, and for this reason medicine and surgery have been always fundamental topics. Fiction and science fiction illustrate clearly the vast variety of expectations that people have from progress in these two important fields. An example of how human vision pushes forward the most secret ambitions is described in *Frankenstein* Mary Shelley's 1818 novel [1], wherein the doctor main character puts together pieces of dead bodies to build a new body and makes him alive with electricity. In the American epic space-opera *Star Wars* (Lucasfilm, 1977) there are also many examples of how medicine is expected to be in a far future: the prosthetic hand that replaces Luke's lost one, in a perfectly equivalent manner; the hibernation techniques; the robotic obstetricians; the fully automated orthopedics apparatus that allows a total replacement of the lower limbs; and Darth Vader's portable automatic respirator. Another interesting example of futuristic surgery has been suggested in *Fantastic Voyage* (20th Century Fox, 1966), which nowadays receives an exaggerated number of mentions at conferences by authors presenting their work in micro or nanosurgery. According to the plot, after an incredible miniaturization process, a submarine about the size of a microbe flows in a patient's ducts to remove a blood clot in his brain. Additionally, the task of producing a correct and fast diagnosis is every doctor's secret dream. In the science fictional series *Star trek* (Desilu Productions, 1966), chief medical officer Dr. McCoy obtains an immediate and detailed diagnosis simply moving a small sensor back and forth over the patient.

Unfortunately, we are far enough away from these goals, and therefore hard, maybe impossible, work remains for us to do along the road ahead. One way to start our endeavor consists of straightening the cooperation between medicine end engineering, because any progress in any technical apparatus that gives enhancements in surgery is based on both the fields of application. Furthermore, a great amount of creativity and interdisciplinary approach is needed to enhance the developments of new tools, which we could refer to as *inventive engineering for surgery* or *engineering-aided inventive surgery*.

The need for cooperation is intrinsically related to the fact that doctors *know what to do*, while engineers *know how to help to make it real* or may even suggest new facilities that open new scenarios for unheard-of operations. At first, progress may have been developed thanks to the creativity of surgeons who had a bit of technical know-how or who dared to experiment with new technical stuff. Again, making reference to another American television drama series, in *The Knick* (AMBEG Screen Products, 2014), Dr. Thackery, chief surgeon at the Knickerbocker Hospital, in case of emergencies, enhances surgical procedures by using the technical equipment in very creative arrangements.

After all these fictional examples, it is a pleasure to mention the exciting and enlightening survey of real cases in surgery recently written by van de Laar [2], where 28 *historical* operations have been described in terms so clear that even an engineer can understand. Among the conclusive remarks, it is very agreeable to assess that, for the moment, *there is as yet no question of computers completely taking over the tasks of human doctors*. However, the described operations show how the cooperation between engineering and medicine has been or could have been important to complete the task with success.

2. From Early Tools to the State of the Art

One way to explain how the cooperation between Technology and Surgery works consists in interpreting it as a customer-provider relationship where engineering offers new technological developments to the surgery' demand. In order to appreciate how strong the surgery–engineering relationship is, let us consider the following classical and fundamental topics in engineering and some of their representative applications:

- Design, strength of materials, and material development, which are required to develop any form of surgical tool;
- Kinematics and dynamics that are necessary to build non-stationary systems;
- Measurements and control that are required in the operational environment;
- Nanotechnology, microelectronics, information technology, and telecommunications that are necessary to develop the operational equipment;
- Pneumatic and fluid dynamics that are fundamental to sustain the vital function of the patient during operation.

Many other branches of engineering are relevant too. All of these capabilities are also necessary to develop most of the new frontiers of surgery, such as

- Smart surgical tools;
- Micro and nano robots for surgery;
- Minimally invasive procedures.

They can be applied to general, lung, gynecologic, head and neck, heart, neuro-spine, vascular, and urological surgery.

Classical Fields of Application

The above-mentioned relationship between engineering and surgery cannot be described in terms of a simple offer-demand interchange. In fact, this cooperation is quite complex and multifaceted a liaison: any possible development in surgery could be supported by a proper collaboration with the engineering counterparts, while almost any new development in engineering could be successfully applied to improve surgical operations. Both alliances need a strong and very integrated partnership and an enduring team work. For all these reasons, the original call for papers from this Special Issue has been open to the following general topics:

- Laparoscopic surgery [3,4];
- Endoscopic surgery [5];
- Robotic surgery [6];

- Natural orifice transluminal endoscopic surgery (NOTES) [7,8];
- New technologies for intraoperative imaging [9].

While more specific topics have been also solicited:

- New technologies for training of residence and young surgeons in minimally invasive surgery [10];
- New technologies for the development of MEMS/NEMS and microsystems for surgery, such as topological [11–13] kinematic synthesis, smart fabrication of multi-DoF crawling tools [14] and operational capability [15–17];
- Transanal endoscopic microsurgery (TEM) [18] and transanal minimally invasive surgery (TAMIS) [19];
- Ethics: ethical issues in the application of autonomous robots in surgery [20];
- Education: new trends in teaching–learning methods and information technology [21].

The next section offers a very short and reasoned review of the contributions that have been included in the present Special Issue. Given the vastness of the topic that this Special Issue deals with, we hope that our effort may have offered a stimulus, albeit small, to the development of cooperation between engineering and surgery.

3. About the Present Issue

Nowadays the science of engineering may support surgery in different ways and through synergies that were hardly conceivable until a few years ago, thanks to the recent advances in applied sciences and technology. In particular, engineering contributions may range from pre-operative assessment to post operative care, and from computer aided-surgery to hardware development for performance improvement of consolidated treatments or novel surgical approaches, such as management and characterization of surgical tools and instrumentation.

Therefore, in this special issue some stimulating contributions are proposed for their valuable applications into the pre-operative field, focusing on modern simulation methods and 3D imaging tools for surgical planning, prediction methodologies [22,23] and data acquisition by means of novel wearable devices [24].

Anyway, the operating field in the context of synergies between engineering and surgery provides most of the advanced and promising solutions. In this regard, further interesting applications are described in the issue: from the control of MRI-compatible robots [25] and the guidance of surgical needles [26], to the use of very complex image analysis methods for surgical tool characterization [27] and the development of novel devices with high functional performances [28] and better ergonomic design for laparoscopic applications [29].

Moreover, solutions and innovations become very forward-thinking when engineering science is challenged with the requirements of minimally invasive surgery, as reported, for example, in the paper [30] where cataract surgery is combined with high frequency deep sclerotomy (HFDS). One more article [31] concerns the novel laser assisted in situ Keratomileusis (LASIK) applications for vision correction in myopia and presbyopia diseases.

Finally, a significant part of modern surgery relies on pioneering efforts to bring about advances in nano and microengineering to the lab and surgical activities. In this issue, an example of extreme miniaturization of the tools used in surgery has been provided by two papers, one concerning the development of a new piezo MEMS tweezer for soft materials characterization [32] and one describing some reasonable progress of MEMS for operations in a surgical scenario [33].

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