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Review Article

Surgery 4.0 *vs.* 4th Generation Robots: Clash of the Titans in the Near Future of Robotic Surgery

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Introduction

Because title of this article contains many terms that most people - including most surgeons - are not familiar with, we will try to describe each one of the protagonists of the predicted "clash of titans" in robotic surgery, beginning around the year 2020.

Robotic Surgery: Actual Achievements

Robotic surgery was first introduced in surgical theaters after the year 2000, bringing a two-sided revolution, one real and one dealing with the "wishful thinking" of innovator surgeons who grew up with Sci-Fi films. These innovators have finally landed to the cruel reality of 2018, without any particular transformation of the health systems due to the presence of robots alone. Instead, their hopes were swept away by the black hole of global financial crisis. Therefore they are still struggling against great opposition by surgeons, patients, hospital managers and insurance companies when it comes down to paying for the increased costs of using the available systems.

Existing Systems

The true dimension of the 'revolution' must be attributed almost solely to the manufacturers and developers of the existing robot that sold thousands of systems and dominated the market over the past 17 years. A great amount of experience has been gathered by the specific system manufacturers since then. A true revolution was there. A radical change of the layout of surgical room took place, as the surgeon no longer stood above the patient but performed the whole procedure sitting over a console, looking through a 3D visualization system and using special controllers (joysticks). Surgeon was offered a three-dimensional, stereoscopic, high-resolution image of the operating field and controlled advanced instrumentation that offered 7-degree freedom of motion and simulated human wrist. These enhanced surgical instrumentation permitted easier maneuverability, precision and intracorporeal suturing in deeply seated and difficult anatomical locations.

Recently, a new operating table has been introduced that can move along with the robotic system without any need for redocking the robotic arms. Additionally, in the latest system, a fifth arm holds the other four to rotate them all together if the surgeon wishes to operate in another quadrant of the abdomen, again without need for redocking. These latter two innovations aim to reduce the OR time required for these frequent changes in relative patient - robot positions.

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Additionally, the system offers PC-connectivity options and surgeons can display useful information at the top of his working screen (patient examinations, CT slices, magnetic resonance reconstructions, etc.) directly from his laptop computer. Newer systems have an infrared camera which, in combination with ICG-fluorescence dye, makes it possible to illustrate the "hidden" renal vessel, bile duct, intestinal perfusion and lymph node anatomy, during harvesting for oncological reasons. With special arrangement of robotic arms, robotics also facilitated Robotic Single-Site interventions, because crossing of the instruments could be reversed digitally by the system, thereby restoring ergonomy. As a result surgeon regained the left instrument in his left hand, but in a stable, robotic platform with all aforementioned benefits.

A '4th generation' of such systems was recently marketed under the name "SP robotic system", which enhances surgical dexterity with new, flexible, snake-like robotic arms and flexible optics that enter the body through small, 2 cm incisions, and offers possibility of a 360 degree rotation of the whole set of instruments. This latest robotic system is expected to solve most of the problems of Single Site Robotic Surgery, to extend its indications and probably revive the discussion about NOTES, i.e. surgery through natural orifices (transoral, transvaginal, transanal surgery).

These are briefly the advantages of existing robotic-assisted technology, which through robotic remote control systems has greatly facilitated the surgeon to perform difficult interventions such as radical prostatectomy, partial nephrectomy and cystectomy in urology, radical hysterectomy, and pelvic lymphadenectomy in gynecology, and esophagus, stomach, colon, pancreas and obesity surgery in general surgery. Many studies of the last fifteen years reported advantages and better outcomes using robotics in the above interventions. However, most of them also admit the problematics of additional costs, as the word "surgical robot" today in surgery automatically means a big difference in the patient's financial burden and insurance objections worldwide.

Robotic Surgeons Ask for More

Certain areas of development in the field are still under research and have not made it through to clinical application yet. Large demands in OR space due to the size of existing systems and difficulty for the staff to move around it during the procedure, are known limitations. Automatic instrument swapping and stapler or clip-applier loading is another one. Integration of control of pneumoperitoneum and other OR parameters are still pending. Checklisting and safety check, still rely mostly on paper sheets and have not been integrated in the current platforms. Augmented- reality aided navigation software making use of the full potential of current developments in radiology, is missing too. Absence of haptic feedback has been advocated by a few authors as a serious deficit of current robotic systems.

Additionally, all data from digital transformation of expert surgeon maneuvering remains unrecorded and unexploited. If this data was stored in some kind of recording media, it could potentially undergo translation of the patterns of motion from surgeon's hands and be used for training purposes as well as for giving 'life' to future autonomous robotic surgical assistants.

Microrobotic vehicles and other MEMS abandoning the 'armed-robot' stereotype are still lagging far behind from any clinical use. And there is even more to expect in the future, such as self-reconfigurable modular robotic instruments, *in vivo* histology sensors, 3D bioprinting instrument tips with stem cells or adipose tissue for real-time sculpturing during defect reconstructions.

Will Robotics Survive Among Surgeons?

Fortunately, robotic surgery seems to be able to cope with and survive, even in difficult financial times, since it has even more to offer in the years to come. Response from the expected competition of the above-mentioned systems has begun to emerge from large brand names known for their work with surgical robotics, but also with network and software innovation.

What is Surgery 4.0?

To clarify the term, "Surgery 1.0" is open surgery, "Surgery 2.0" laparoscopic, "Surgery 3.0" robotic-assisted with remote control systems, and "Surgery 4.0" information-based, "intelligent" robotic surgery. In this new age, the robotic system will not be a simple extension of the surgeon's eyes and hands, but will also deliver cognitive processes, i.e. it will be able to think. Surgery 4.0 will get "flesh and bones" into a digital platform that will include robotics but will not only focus on them.

The new 'robot' will provide important information to the surgeon to guide him through tough decisions, while promising to automate certain surgical maneuvers when the surgeon asks for it. It is expected to have software to identify the particular anatomy of the patient, guiding the surgeon with a GPS-like system. Through improved, advanced communication systems, it also promises to re-introduce the concept of "tele-surgery" and "tele-mentoring".

If one adds the Internet of Things capabilities to each of the smart tools of this new era, one maybe able to understand how much information will become available to the surgeon's hands. This is exactly what Surgery 4.0 is all about. It is supposed to make use of the power of Big Data, Artificial Intelligence and Neural Networks (AI) to save surgeon maneuvering styles from all parts of the world and be able to recognize " similar "conditions and patterns through models of pattern recognition, to react appropriately at the right time and to advise the surgeon in the decision-making process [1,2].

What Kind of Revolution are we Talking About?

The answer is that it is not just a technological revolution, but an effort for a radical transformation of the business model of health around the world. In other words, supporters of Surgery 4.0 intend to change the health system altogether, minimizing the costs of surgery and making technology available literally everywhere; not just in rich societies and large urban centers. They are talking about democratizing surgery, i.e. every single surgeon will be assisted to carry out the operation, even the most difficult ones, everywhere on earth [3-5].

Ethics

Surgeons are by nature a very conservative population of doctors (even robotic ones) and although this technology outburst sounds really astonishing, one should be very cautious when commercial titans wish to clash inside our surgical rooms. As it is known, marketing is not a product battle, but a "battle of impressions in the minds of consumers".

On the other hand exploitation of 'big' (but still sensitive) data of patients should be secured from socio-economic and privacy risks and should be kept isolated from health marketing interests and insurance motives; it must aim solely to the best outcomes for patient care and research purposes [6-10].

Surgeons should remain skeptical in front of these vast changes and selectively adopt new technology with proved benefit from randomized trials. In the end of the day, responsibility for the life of patients ends in their hands, regardless of the instrumentation and technology used.

Do we Need More Robots or Better Surgeons?

Is the solution to the problem of today's health systems around the world, an over availability of cheap robotic systems in every remote provincial city in the world and for any surgeon of any education and any experience as promised by Surgery 4.0? And will it address more ways to better educate young surgeons in the basic principles of surgical technique, anatomy, pathology and oncology? Will Surgery 4.0 be able to break this eternal problem, simply with diffusion of more technology and falling prices?

With the existing robotic systems, but also with conventional laparoscopy, even with the simple scalpel, if the surgeon does not know what he is doing, neither will the robot do... On the contrary, good outcomes in the majority of studies come from centers of excellence and from experienced and well-trained surgical teams.

In the age of Internet of Things and as the available information grows gigantic, every surgeon needs to be updated and trained even harder, and every patient needs to be well-informed and skeptical, and make an informed selection of his surgeon (not of a robot, or a cheaper robot, or a cheaper insurance coverage deal).What we are discussing here is surgery that involves himself and his life.

We hope that Surgery 4.0 will respect and address these important parameters, opening the way into a brighter future for surgery and for the good of health care. The future is near ... So we'll all get to find out soon enough.

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