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Robotic Surgery, Is It the Future?

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Abstract

The surgical community has become more interested in robotic surgery in the last decade as the volume of related articles has significantly increased. This short article aims to summarize the main points to consider in relation to robotic surgery.

Keywords: Robot, Robotic Surgery

Background

The term robotics is derived from "robota" Czech word meaning "servant" or "worker" [1]. The robots have been used explore the depth of the oceans, in rescue missions and in the motors industry to replace workers on the production lines aiming to prevent human injuries [1]. It is perceived that robots have some form of artificial poor intelligence [1,2]. This intelligence is principally of practical importance as the difference between human–human interaction and human–robot interaction should be understood when operating the robot [2] but discussing that in depth is beyond the scope of this article. Robots can be used in physical medicine and rehabilitation, prosthetics, diagnosis, and physical and social assistance to disabled and elderly people [1,3] but this article will primarily focus on using robots in surgery. The idea of using robots in surgery might have begun with the concept of a surgeon performing an operation at a distance without the physical existence of the surgeon who, in principle, could be in a different part of the world [1]. For practical purposes, robotic surgery should be regarded as a variant of laparoscopic surgery [4].

Advantages

The essential advantages of robots are the high definition, three-dimensional (3D) stable camera which provides a much more magnified view than the laparoscopic camera as the robotic surgeon sits in a console (two consoles if the operation is performed by two surgeons) and controls effector robotic arms (usually three or four arms) which have greater maneuverability than the human wrist thus providing better angles for the operator, keeping in mind that the assistant, who stands at the operation table, uses a laparoscopic rather than a robotic screen [1,3,5]. The comfortable position of the surgeon is expected to minimize the adverse effects of fatigue allowing surgeons to perform more operations per day without decrease in performance [3,6]. The ability of the robot to filter the physiological human tremors gives it an advantage over the conventional laparoscopic surgery [5]. Robots, therefore, improve the surgeon's dexterity, ergonomics, and visualization [7]. It is intended that by increasing dexterity, controllability and precision to surgeons, robots would allow the execution of more precise and safer operations [3]. It is arguable whether all these benefits can have an impact on the work and productivity of the surgeons potentially extending their professional career by allowing them to reach expert levels earlier in their careers and to maintain high levels of precision and dexterity for longer [3]. The learning curve, particularly for trained laparoscopic surgeons, is expected to be shorter than conventional laparoscopic surgery as robots are meant to be more intuitive than laparoscopy although the curve is still lengthy and profound [4,5,8]. Virtual reality exercises have been introduced to enable surgeons to practise their robotic surgical skills, thus shortening their learning curve and that, at least in theory, could shorten the operation time, decrease complications and improve patients' safety [8].

Disadvantages

The main disadvantages of robots are the higher costs, increased surgical time and the total loss of tactile sensation [5,6]. Two points have to be considered in relation to these disadvantages: 1. A part of the increased surgical time is spent in docking the robot 2. The loss of tactile sensation is much more than in conventional laparoscopy where the surgeon still keeps some sensation which, in turn, has always been regarded as a disadvantage of laparoscopy compared to open surgery [5,6,9]. Whilst it is conceptually mechanically easier to perform robotic hand knots, being three dimensional, compared to laparoscopic surgery, the total lack of tactile sensation somewhat negates this advantage as the tension on the knot relies only on the surgeon's vision [5] which might make it practically less secure and more difficult. Furthermore, injuries may go unnoticed with the total lack of tactile feeling [5].

New Robotic Technologies

New robotic technologies may produce cheaper systems and new developments such as haptic and tactile sensing and force feedback technology could potentially solve one of the real drawbacks of robotic surgery [5,10,11]. Emergence of competitive companies may indeed contribute to tackling the high cost issue. Future developments aim to decrease variability of performance with an overall shortening of the learning curve [10]. Indocyanine green, which can be used to identify vessel perfusion and differentiate tissue density, may be used in robotic surgery with the view to helping in intraoperative identification of vascular, neurological and oncological tissues [12].

Robot Uses in Surgery

Robots have been used in a variety of operations for benign and malignant conditions. They have taken more roles in prostatectomy, particularly when dissecting the bladder neck, and in partial nephrectomy and started to take a role in radical cystectomy whilst their benefit in radical nephrectomy has been more debatable [9,13,14]. Their role in adrenalectomy is still being evaluated [9]. Robots have been used for robotic guided cardiac radiosurgery for atrial fibrillation, in minimally invasive mitral valve repair and replacement and in paediatric urological operations with different reports on patient's suitability and selection [7,15-17]. There are a growing number of research papers on robotic gastrointestinal surgery.

Most studies have been retrospective addressing the short term results of robotic surgery. Interpretation of results could be more complex than the initial studies on laparoscopic surgery as robots have to be compared with both open and laparoscopic surgery meaning there are, ideally, three arms for comparison.

Urology

In urology, retrospective studies comparing post-operative complication rates, oncologic outcome, disease recurrence and mortality in patients who underwent either open or robotic-assisted radical cystectomy during a 10 year contemporary period showed that open radical cystectomy and robotic radical cystectomy patients have comparable post-surgical outcome profiles whilst the robots may offer additional benefits in terms of lower surgical blood loss and reducing the need for transfusion, although the cohort of patients here is small [13].

Laparoscopic Gastrointestinal Surgery

Whilst laparoscopic distal gastrectomy was comparable to open distal gastrectomy in terms of short and long-term outcomes and is now considered a safe and technically feasible treatment option for early-stage gastric cancer, robotic gastric surgery did not show any tangible advantages over laparoscopic distal gastrectomy in terms of blood loss, complications or short term outcome [6]. Nevertheless, compared with open surgery, laparoscopy exhibits comparable or poorer retrieval of lymph nodes whilst robotic surgery shows comparable or better retrieval of lymph nodes than laparoscopy which means that robotic surgery may be able to address this significant weakness of traditional laparoscopy [4].

Robotic surgery did not show significant advantages over laparoscopic distal pancreatectomy [18] whilst the recurrent laryngeal nerve injury was reported to be less in robotic oesophagectomy which is thought to be due to the high definition 3D image of the robotic camera [19].

Laparoscopic Colorectal Surgery

Laparoscopic colorectal surgery has progressively expanded but it has technical limitations such as poor ergonomics, two-dimensional view and coning that may influence surgery in narrow anatomical fields such as in the pelvis during rectal surgery [20]. It is, therefore, hoped that these limitations would be overcome by robotic surgery. A review by Staderin et al. [20] addressing the safety, feasibility, complications, operating time, blood loss, postoperative recovery, number of harvested lymph nodes, tumour involvement of circumferential margin and autonomic dysfunction following robotic rectal cancer showed that robotic surgery is as feasible and safe as conventional laparoscopy in the treatment of rectal cancer, with the main drawback of longer operating time. However, the results of the studies addressing the other parameters were controversial and did not show the superiority of robotic surgery with any degree of certainty apart from the autonomic dysfunction where robotic surgery was expected, rather than evidently proved, to be more favourable than laparoscopy which, again, is understandable in view of advantages of the robotic camera.

Robotic Uses for Biopsies

Robotic assisted stereotactic biopsy of intracranial tumours such as diffuse intrinsic pontine glioma and image-guided automated robot for MRI breast biopsy have been used with encouraging results in terms of accuracy, repeatability, safety and lack of significant distortion attributable to the robot, projectile risk, and unacceptable levels of heating but this is still restricted to a few centres [21,22].

Future Developments

In addition to the new technologies mentioned above, the future may witness some developments which are hoped to improve the shortcomings of robotic surgery such as [23]: 1. The variable use of optical devices in all trocars, 2.The new geometry may allow the operation to be performed in all spatial directions without re-docking, 3. Longer instruments provide greater flexibility as well as better access, 4. The possibility of working simultaneously on two parallel consoles would shorten the learning curve, reduce complication rates, and facilitate the training of surgeons, 5. The freedom of movement can be maximized by the introduction of one or more additional working trocars, 6. Smaller trocars can help address the disadvantage of robotic compared to laparoscopic surgery as the former requires the use of larger trocars and hence is associated with larger scars.

To weigh out: The main attraction of robots is the high definition, three-dimensional camera which makes it easier to operate and shortens the learning curve compared to laparoscopy but robots are disadvantaged by the cost, lack of tactile feeling and longer operation time. If we consider that studies did not objectively demonstrate a significant benefit over laparoscopy, which somewhat contradicts the surgeons' common sense and expectations, we cannot find an immediate or strong reason to think that robotic surgery, at the moment, will easily supersede laparoscopy. On the other hand, the developing technology might "purify" the robot of its disadvantages keeping or even improving its attractions. Furthermore, most of the studies do not provide level I evidence and that may change with improving the learning curve of the surgeons and the technology of the robots. Robots are a reality now and they cannot be simply dismissed without strong evidence. Like any new development, a sufficient period of trial and improvement has to be allowed before the final assessment conclusion can be drawn.

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