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ORIGINAL ARTICLE

Establishing a successful robotic surgery program and improving operating room efficiency: literature review and our experience report

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Abstract

The benefits and outcomes of robotic surgery are well established in the literature across multiple specialties. The increasing need for and dissemination of this technology associated with high costs, demand adequate planning during its implementation. Therefore, after years of training several robotic surgeons and establishing multiple robotic programs worldwide, the purpose of this article is to focus on the necessary elements in the initial phase of establishing a robotics program. We summarized in our article crucial factors when implementing a robotic program. Therefore, we explained in detail the critical aspects of the program design, implementation, marketing, research and outcomes, and ultimately improving efficiency. The creation of a robotics planning committee composed of several hospital individuals contributes in different lines of work such as cost evaluation, staff training, and OR modifications. A multidisciplinary approach and a robotic lead surgeon are also recommended to guarantee surgical volume and satisfactory outcomes. Furthermore, market analysis should evaluate the competition with other centres and potential surgical candidates in that area. Data collection should also be considered a vital element of the program organization, which assures quality control and helps to diagnose any program deficiency. We believe that the robotic program should be individualized according to the economy and reality of each centre. The success and duration of a robotic surgery program depend on long-term results. Therefore, careful planning with a robotic committee defining the types of procedures to be performed and appropriate multidisciplinary training to avoid surgery cancelations are crucial factors in establishing a successful program.

Keywords Robotic surgery · Robotic surgery program · da Vinci robot

Introduction

It is currently debatable if the gold standard for radical prostatectomy is the open or robotic approach; this is based on the optimal results obtained with the robotic approach, and the worldwide tendency to have a da Vinci technology system. Today, the robotic surgical system has become a common used tool with a rapidly expanding market for minimally invasive surgeries in major metropolitan hospitals. In most parts of the world now, more institutions have the opportunity to offer their patients the latest technology as well as laparoscopic surgery [1, 2].

Robotic surgery is a perfect example of how technology has revolutionized the surgical field. Open surgery was initially followed by laparoscopy and now robotic assistance. At the same time, changes have occurred in equipment, instruments, and surgical/technical devices. Everything is aimed at improving precision, accuracy, and results, shortening recovery time, decreasing blood loss, and ideally also reducing costs [3].

Robotic surgery was partially developed in order to deal with the anatomical challenges of operating in deep confined spaces such as the pelvis. It allows better visualization by three-dimensional (3-D) vision and 10× magnification, motion scaling, and tremor elimination. All these advances have been oriented towards better perioperative, functional and oncological results as well as improving the surgeon's learning curve [4].

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A successful robotic program is appealing to every hospital, however, there are many requirements needed to establish it as a self-sustainable program in the current healthcare market [5]. A thorough initial design and implementation leads to the execution of clinical services, which meet previously established goals. Once the execution phase is established, the next step is to focus on maintenance and growth to maximize the benefits of the program.

Purchasing technology alone is not enough. Developing and implementing a robotics program requires intense training, marketing and most of all, the dedication and passion of surgical team members ready to take their surgical experience to the next level. With a well-developed robotics program, a hospital has the opportunity of great financial success in addition to providing patients with cutting-edge healthcare.

Overall, the business models are idiosyncratic, they depend on each hospital and the possibilities of providing equipment and qualified personnel; it also depends on each country and its economy. Even robot prices may have slight changes from region to region. That is why we give a general but very useful organizational ideas which have helped us at the AdventHealth Global Robotics Institute to form what is today a successful program. The purpose of this article is to focus on the different elements involved and necessary in the initial phase of a robotics program rollout.

Program design

Business development plan—market analysis

Before starting the program, it is crucial to have a business development plan with an evaluation of the expenses related to the arrival of the robot and its operation. Therefore, this should include the direct costs (cost of the robot) and also the indirect costs (associated material, training of staff) [4].

Operating room (OR) modifications could be necessary for the better functioning and support of the console and other equipment. A key and necessary action is the recruitment of a lead surgeon or his training to ensure the proper and correct development of the program.

Careful planning with a creation of a robotics committee is the first step to establish a successful robotic program. Ideally, the committee should be composed of several hospital individuals who can contribute in different lines of work: a hospital administrator, an aneasthesiologist, a surgeon, and a trained nurse [5]. The inclusion of a member of each group to the robotics team from the beginning will increase the probability of success and will provide a more fluid transition once the program starts.

Furthermore, a market analysis should evaluate two aspects: health competition and the patient population [3]. It is also mandatory to evaluate the development of other hospitals' robotic programs (in terms of robotic surgery, their growth and influence on the population's healthcare) as these aspects are crucial to improve based on other centres' experiences.

The second step is to estimate the patient population. Robotics has the appeal to new patients for two main reasons: the robotic program itself and the idea that they will be treated in a technologically advanced centre. Consequently, different studies have shown that the interest of patients in robotic surgery is growing [6]. Satisfactory results have fed the demand of the patients of robot-assisted surgery to create a solid base for the implementation of this technology in the operating room. The literature demonstrates that recent trends indicate a continuous increase in demand for robotic prostatectomy [7] in part due to widespread and persistent marketing of robotic programs.

When starting the program, there are two possible situations that the hospital must consider in terms of staff. First, it is necessary to know if there is any surgeon interested in doing robotic training; the other option would be to recruit and appoint a mature robotic surgeon as director of robotic surgery at the institution.

Having an experienced physician in this field will provide a solid foundation for the program and will be essential for a satisfactory start. If this is the case, the institution ensures a shorter growth curve compared to the case in which the surgeon has to be trained [2].

Another key step to a successful robotic program is the surgical volume, connected strictly to the learning curve and to the quality of outcomes. According to the experience of The Ohio State University, three to five cases per week, during the initiation of the program, are necessary to obtain continuity in the learning curve [8].

The number of cases necessary for a program to be sustainable has already been calculated by institutions with successful programs at the beginning of the robotic surgery era: it should be three to five cases a week. This number guarantees economic benefits and a growing demand linked to the improvement of results. The OSU program went from 40 to 350 cases per year in 5 years by following this guideline [9]. A multidisciplinary approach is also recommended in order for the program to survive, this way the diversification guarantees surgical volume and therefore, a higher probability of success.

It may also be wise to ensure that, in some centres, surgeons undergoing robotic training sign an agreement that once trained, they are exclusively committed to the organization that sought them to succeed.

Finances—purchase of a robotic system and surgery costs

The da Vinci robotic system has a significant cost associated with its purchase, ranging from 0.5 to 2.5 million USD, depending upon the type of system acquired and the overhead charges associated with the local agent (distributor). Additionally, there is a per-instrument, per-case disposable fee of approximately 700–3500 USD, and a maintenance contract of 80,000–170,000 USD per year/per system [8]. The aforementioned values represent fixed costs. The variable costs are those to be taken into account for the execution of the surgery, such as disposable items or materials, medications, etc. Also, increasing the use of the robot will have a direct impact on cost reduction because a higher number of cases will increase income thus advancing the program, reducing surgical time and improving results.

Other associated costs to be taken into account: the marketing program, patient education and OR employee training. It is also worth mentioning that other options to reduce costs include the recruitment of new surgeons already trained in robotic surgery.

Obtaining financing for a $2 million robot is challenging. Finding at least one source that meets the institution's needs may be vital in the acquisition of a new platform [1].

Examples of funding sources include:

- State and federal programs
- Foundation grants
- Donations
- Government programs (i.e., economic stimulus package)
- Grateful patient programs or memorials
- Donations from employees and doctors (for example, monthly deductions from paychecks)
- Loans.

Implementation

Operating room design

The operating room (OR) has to be designed with the necessary modifications to accommodate the console, robot, anaesthesia equipment, operating table, instruments and auxiliary equipment while maintaining safe spaces for the circulating staff (Fig. 1).

A sufficient stock of surgical instruments is imperative, since they have a limited number of uses, and it would be extremely inconvenient that any instrument should fail during a procedure. There should also be extra lenses (scopes) or any other spare part that might become necessary in case of any equipment malfunction.

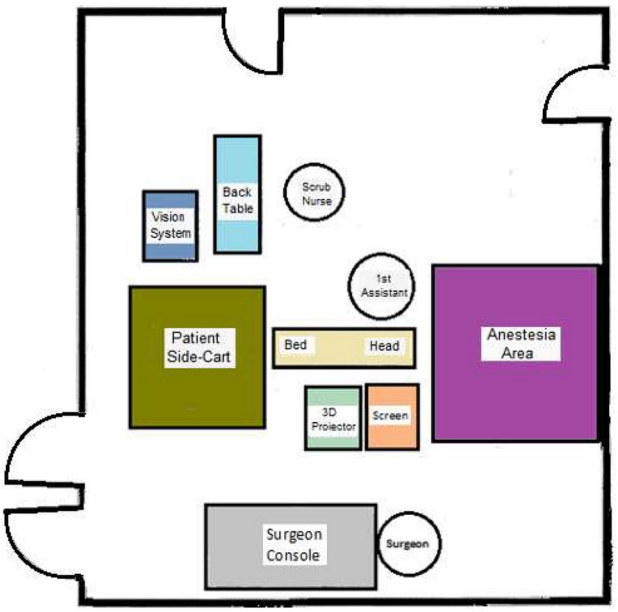

Fig. 1 Robotic operating room setup: designed to accommodate the specific needs of the robot, OR team, and patient

It is also recommended to have a dedicated robotic OR. This will avoid the timely and arduous task of transferring the robot between rooms and it will also avoid damages that may occur during transport. The proper setup is essential to the development of an efficient and safe operating room [2, 4].

Finally, it is also beneficial to have dedicated areas reserved for education, where anybody involved in the robotic program (trainees, fellows or visitors) may observe both the performance of the team and the details of the interventions.

The robotic team

Once the operating rooms have been adequately installed, creating a functional and experienced robotic team is crucial for the program's success.

The lead surgeon

The designated person who represents protects and knows all aspects of the program is vital and should collect permanent surgical data. Also, such person is in charge of the management and education of patients, the public and other surgeons in general [10].

The ideal situation is the recruitment of a lead surgeon with an already finished learning curve, guaranteeing more consistent results that can be achieved from the very beginning of the program. The learning curve is measured by the impact on the oncological and functional results (i.e.,

patient's quality of life). It is understandable that with greater surgeon's experience better results are likely to be obtained and so, patient's and surgical team's satisfaction are subsequently improved.

The lead surgeon has the task of performing surgery and training/coordinating the team in the operating room. This surgical proficiency and ability to communicate and create a scientific network are essential skills to run the program.

Due to the mild differences in internal processes among various institutions, there are currently no training manuals for members of the robotic team. Each institution should have its own guidelines (either to adopt or to develop them); these are usually created according to the needs and details that emerge during the first surgical cases [2].

The keys to training lead surgeons are based on improving their knowledge of the da Vinci system with lab exercises on cadavers and/or porcine models; the next steps are case observations and video-based learning and if possible, it is recommended to perform the first procedures with a proctor.

After a complete training, the appropriate selection of patients is an essential element to commence with. The ideal situation is to begin with less demanding cases. The surgeon needs to take into account factors such as the patient's comorbidities, prior surgeries, prostate size, cancer characteristics, and preoperative sexual score [4].

The OR team (nursing staff—surgical assistant)

The team's competence can improve or ruin the program. The coordination among the team members during the procedure is essential to eliminate delays. Nurses are necessary for correct instrument configuration/organization and also in solving technical issues that may occur with the equipment during the surgery. Moreover, well-trained nurses allow the surgeon to maintain rhythm and concentration during the procedure. Robotic surgery is unique in the sense that the leading surgeon is not directly in the operating field. Therefore, this is the reason that the first assistant and the nursing staff are of utmost importance in these procedures [11].

The number of staff needed depends on the goals of the program and its resources. It is important to remember that the rest of the team does not have a tri-dimensional vision as does the surgeon, so that certain movements might have less precise, although they should be effective. In order to improve OR efficiency, a minimum of two surgeons, one nurse, and one anaesthesiologist are needed.

The tableside assistant plays an active role in the surgery in terms of suction, irrigation, retraction, cutting, supplying sutures, and the extraction of the final specimen. It is crucial to have a tableside assistant with laparoscopic skills to improve the efficiency and fluidity of movements. In some high-volume and experienced institutions, highly qualified nurses replace assistant surgeons with successful management thus reducing costs [3]. These individuals will remain constant, while residents, fellows and surgical assistants may often change. This reproducibility maintains the quality and provides the operating surgeon with the reassurance of consistent assistance and outcomes at all times.

The whole team should know all the steps of the surgery to achieve greater efficiency, better results, and shorter surgery time. This is the cornerstone that makes the team more consistent. The ideal scenario is that all members know the surgical procedure, and also guarantee continuous education for future team members.

OR team education All the personnel that will be involved (nurses, surgical technologists, and anaesthesia care providers) are also sent to observe robotic surgery at an experienced clinic, providing them the opportunity to observe and get acquainted with the role they will perform. The next phase consists of training with the robotic company representative. This practice aims to educate the OR team on all the electronic devices needed for robotic surgery and how to:

- Connect the robotic system components
- Calibrate the robot for optimal use
- Troubleshoot technical problems that may arise during a procedure [1].

The Madrid experience: the perspective from a public European hospital In our experience in a European Centre, we also believe that to develop and run a successful robotic surgical program, it is necessary to perform specific actions avoiding cancellations with short turnovers, start surgeries on time, provide enough instrumentation and supplies for the workload, and the most important is having a dedicated and motivated team.

The OR personnel is the cornerstone for any safe and efficient robotic surgery. Since the beginning of our robotic program, we trained and maintained our experienced staff over the years. In our centre, we employ a primary surgeon, an experienced first assistant (in our case, another robotic surgeon), a scrub nurse, a circulating nurse, a nursing assistant, and one anesthesiologist. With our experience visiting and creating different programs worldwide, we believe that this OR staff configuration is very similar between most centres.

Furthermore, dedicated and trained staff are critical for the successful development of a robotic OR. Of paramount importance is the understanding of the procedure by the team. During each step of the procedure, every single member of the team plays a key role. Therefore, even if the centre has a restricted financial condition, patient safety and efficiency will be maximized with a devoted, well-trained, and consistent team.

Marketing

Numerous studies have shown the increasing interest that patients have in robotic over open procedures [6]. The crucial factors are the cutting-edge technology, satisfactory results, and previous experience from patients (word of mouth) and physician referral that boost the demand for these procedures.

We advise an appropriate promotion campaign for newly created robotics programs. Showing the benefits of this technology associated with ease access are main factors to attract patients to the institution. Some reports show that a decrease in retropubic radical prostatectomies (RRP) was noted in non-robotic hospitals after the implementation of a robotic surgery program in neighbouring hospitals [12]. Collaboration among surgical specialties, also on the marketing side, is a solution to cover the costs of the advertisement.

Advertising and profiling articles from newspapers and magazines should not create false expectations for patients; in other words, all the information provided to the public should be veracious and compatible with the literature reports. Hospital and surgeon websites ought to have information about robotic services provided with suitable and useful links [13].

Furthermore, in order to expand the robotics program, a website is a vital diffusion tool. However, it is recommended only when satisfactory results and a solid team have been obtained. Also, conferences should be organized by the hospital and directed to patients, doctors, and the public in general. Conferences should be held within the hospital and in other locations to provide interaction with the community [2].

Finally, social networks such as Facebook, Twitter, Instagram, and other social media platforms have emerged as a powerful tool to keep surgeons connected to the general population, which leads to potential patients. Therefore, it is possible to convey to them informative messages about health, prevention, and healthy habits, along with publications related to robotic surgery.

Research and outcomes

Data collection should be considered the key element of the program structure, which assures quality control and helps diagnose any program deficiencies [9]. The database must evaluate different clinical parameters such as surgical time, hospital stay, blood loss, postoperative pain, time to return to normal activity, continence, erectile dysfunction, surgical margins in cancer surgery among other variables. Other additional parameters to assess quality is the degree of consumer satisfaction, global economic costs and the economic cost of each procedure.

Additionally, an internal review should be carried out annually and the ways to improve the program should be discussed among the robotic team and coordinators. It is also advisable to present the experience to colleagues during meetings and scientific events or to report it as peer-reviewed papers to improve quality and to share knowledge and findings. A complete collection of surgical videos is mandatory for surgical audits or for the training of fellows and residents [4].

Improving efficiency and quality

There is an urgent need in our health system to use resources as efficiently as possible. Therefore, the operating rooms (ORs) have an important impact on patient flow through the hospital [14, 15].

The most important factor is efficiency which refers to eliminating wasteful activities and focusing attention on patterns and beneficial tasks. Increasing efficiency in the OR allows for improvements in quality and success. Therefore, OR efficiency should be defined as the time the room is in use and not available to perform other surgical procedures [16]. When defined in this way, OR efficiency includes three different times points:

- Pre-surgery time.
- Surgery time.
- Turnover time.

Pre-surgery

Avoid cancellations

Case cancellation is a term that includes many different entities. The largest study of OR cancellations performed at over a hundred VHA (Veterans Health Administration) facilities, described a cancellation rate of 12.4%. The cancellation reasons were assigned to six categories described in Table 1 [17].

An integrated preoperative preparation system may significantly decrease the "patients' reasons" cancellation rate, particularly the "same-day cancellation", the most damaging of all cancellations in terms of OR efficiency [18].

To avoid these situations, we follow some strategies:

1. Provide high-quality pre-op counselling, where patient questions and concerns are answered in advance and in a satisfactory way. The patient is also provided with a "Preoperative Package" in which all details of the pro-

Table 1 Classification system for cancellation reason used by VHA system

Patient reasons	Patient refused/ no consent, transportation issues, preoperative instructions not followed or patient not instructed adequately, patient substance abuse, etc
Facility reasons	Broken equipments or not available, no ICU beds or hospital beds, scheduling error, staff shortage
Work-up reasons	Abnormal test, change in medical status, anesthesia work-up needed, etc
Anesthesia reasons	Staff not available
Surgeon reasons	Staff not available
Miscellaneous	

cess are described, i.e. medical clearances, consents signed, labs, radiology (MRI, CT Scans), nuclear medicine (BS if needed), what medications to stop and when to stop them and specifics on preparing for the day of surgery.

2. Ensure that all the above-mentioned paperwork is completed at least with 4–6 weeks before the procedure;
3. Revision of all paperwork by a qualified and dedicated nurse and/or provider; If all information is in order, the patient is then assigned a surgery date.
4. Our concierge will call the patient three days before the surgery which serves two purposes: First, to address last-minute doubts that the patient may have and second, it reinforces the patient's trust.

Following all these strategies, our group has been able to reduce cancellation rates year by year. It is evident that the effectiveness lies directly on the quality and guidance of the team involved during the entire process, i.e., from the first consultation all the way to the day of surgery, with the goal of avoiding any confusion that may lead to delays in the process or even the cancellation. During 2019, our surgery cancellation rates were less than 1% (5 patients) with approximately 1200 cases; the most common cause was prolonged coagulation times which speaks of the efficiency of the process.

Start on time

It is essential to have the patient's medical records and clearance ready, along with any other necessary documents to start the procedure on time [19]. In a well-functioning OR, the cumulative delay should be less than 45 min per 8 h day. Therefore, the OR manager should properly determine the patient arrival time (not too early or late), as well as ensuring that the OR staff is ready on time.

Our team has access to two operating rooms (Monday–Friday), each one with a complete working surgical team that worked staggered, meaning that while the first case is under way, the second room is being prepared for the following patient and OR itself to start the case once the preceding has ended. This allows for an optimal use of OR time. With this kind of structure, we manage to perform an average of 4–5 cases a day in each surgery room, thus carrying out 8 or 10 cases daily.

Surgery

Avoid prediction bias

This is the bias in case-duration estimates per eight hours of OR time. Efficient ORs should have a bias in case-duration estimates of less than 15 min per eight hours of OR time [20]. An easy way to avoid this issue is to consider the anaesthesia time and turnover when planning the OR schedule.

Room requirements

The OR must be large enough to accommodate the *da Vinci* Surgical System, anaesthesia equipment, back tables, monitors, staff, and still have room for the circulator nurse and other OR personnel to move freely around the OR without risk of contaminating the field.

In our experience, having exclusive robotic rooms enhances productivity, decreases turnover time and limits potential damage to the robot in transport. Therefore, operating rooms were designed at our institution to accommodate the specific needs of the surgical robot, OR team, and the patient [2].

Equipment and supplies

The equipment needed in a robotic OR, beyond the equipment already available in any other OR used for laparoscopic cases, includes equipment obtained from the robot vendor: reusable robotic accessories (e.g., scopes, light guide cables, and trocars), limited-life reusable robot arm instruments (e.g., grasper, needle drivers, scissors), and disposable robotic supplies (e.g., drapes, cannula seals, insufflator and other disposable robotic accessories). If the room gas is not available, a spare CO_2 tank is recommended to switch to a full tank when the first one empties without losing the pneumoperitoneum and time. Other necessary types of equipment include scope warmer, suction device, irrigator and chairs (Fig. 2).

Fig. 2 Table setup

It is also advisable to have enough instrumentation to perform all scheduled cases plus one. This allows back-to-back procedures without having to wait for the equipment to be cleaned as well as, maintaining a working supply of backup instruments that have been sterilized and are ready to use [21].

The robotic team

Robotic surgery is labour-intensive in terms of OR personnel. The individuals necessary to run a successful operating room may vary depending on the workload and resources.

The first assistant must be a fully trained laparoscopic surgeon or physician/surgical assistant with as many robotic surgeries to accomplish an experienced bedside assistant. They must be highly trained personnel with adequate knowledge of surgery to ensure timely and efficient cooperation.

Another key to running an efficient OR is the task to overlap for the critical personnel of the room: surgeon, first assistant, scrub nurse, circulating nurse, and anaesthesia. During each step of the procedure, every single member of the team plays a vital role [16].

Turnover

Long turnover times frustrate anaesthesiologists and surgeons, reduce professional satisfaction, and reduce surgical workload if the surgeons have a choice of another hospital to do their cases. It is for this reason that turnover time receives much attention from OR managers.

A length of time between cases that is longer than a defined interval (e.g., 1 h) should be considered a delay; in turnover, a note should be filled to identify the reason for the delay. Usually, the delay peak happens in the middle of the workday because that is when most turnovers occur [22].

Fewer than 10% of prolonged turnovers should last longer than 60 min in well-functioning ORs [20]. Managers can aim to reduce prolonged turnovers by focusing efforts on the times of the day in which the most prolonged turnovers occur. Strategies based on rewards have shown to be effective in reducing turnover times.

At the AdventHealth Global Robotics Institute we have achieved an adequate/optimal patient turnover rate; currently the duration is between 10 and 14 min on average per case. Having two operating rooms available with fully trained personnel and complete equipment automatically leads to a low squander of effective time.

Conclusion

Establishing a robotic program demands time and a great deal of work. A robotic program, to be competent and efficient, should have adequate infrastructure and must be individualized according to each centre resource reality. The high initial and operational costs can be offset by the patient volume, which could be attained when performing interdisciplinary work. Our goal should always focus on avoiding surgery delays. Finally, it has to be understood that the profit is unusual in the first year of the program due to the high initial investment required to establish the program. Hence, the main success and duration of a robotic surgery program depend on long-term results.

Compliance with ethical standards

Conflict of interest The authors Camilo Giedelman, Marcio Covas Moschovas, Seetharam Bhat, Lauren Brunelle, Gabriel Ogaya-Pinies, Shannon Roof, Cathy Corder, Vipul Patel, Kenneth J. Palmer, have no conflict to disclose related to the production of this article. Dr. Vipul Patel is consultant for Exact Sciences/Genomic Health, Decipher/Genomic DX, Active Surgical, and AVRA.

References

1. Zender J (2010) Developing a successful robotic surgery program in a rural hospital. AORN J 92(1):72–83
2. Palmer KJ, Patel V (2012) Launching a successful robotic program. In: robotic urologic surgery. Springer-Verlag, Berlin, pp 11–17
3. Pereira-Arias J (2019) How to build a robotic program. Archivos Españoles de Urologia 72(3):227–238
4. Rocco B, Patel V (2009) Building a robotic program. Scandinavian J Surg 98:72–75
5. Luthringer T (2012) Developing a successful robotics program. Curr Opin Urol 22(1):40–46
6. Mf B (2009) Patient perception of robotic urology. BJU Int J 103:285–286
7. Johnson EK, Wood D (2010) Converting from open to robotic prostatectomy: key concepts. Urologic Oncol 28:77–80
8. Intuitive Surgical, "www.intuitive.com,". Available: https://isrg.intuitive.com/static-files/880bf027-e866-4c32-b910-5332467cd8dc. Accessed Sep 2019.
9. Palmer KJ, Patel V (2008) Launching a successful robotic surgery program. J Endourol 22(4):819–824
10. Estes J, Stephanie M (2017) Best practices for robotic surgery programs. J Soc Laparoend Surgeons 21(2):1–8
11. Allona A (2007) Establishment of a robotic program. Archivos españoles de urología 60(4):371–374
12. Madeb R (2011) Theimpactofroboticsontreatmentof localized prostate cancer and resident education in Rochester, New York. J Endourol 25:573–577
13. Matsunaga GS, Costello AJ, Skarecky DW, Ahlering TE (2007) Essential elements of building a robotics program. In: Patel VR (ed) Robotic urologic surgery. Springer, London
14. Thorburn H (2014) Analysis of operating theatre utilisation to drive efficiency and productivity improvements. Stud Health Technol Info 204:163–168
15. Cima RR (2011) Use of lean and six sigma methodology to improve operating room efficiency in a high-volume tertiary-care academic medical center. J Am Coll Surg 213(1):83–92
16. Fagin R (2011) Achieving efficiency in the operating room: step by step. In: robotic in genitourinary surgery. Springer-Verlag, London
17. Argo JL (2009) Elective surgical case cancellation in the Veterans Health Administration system: identifying areas for improvement. Am J Surg 198:600–606
18. Chiu CH, Lee A (2012) Cancellation of elective operations on the day of intended surgery in a Hong Kong hospital: point prevalence and reasons. Hong Kong Med J 18(1):5–10
19. Dexter F (2005) Bayesian prediction bounds and comparisons of operating room times even for procedures with few or no historical data. Anesthesiology 103:1259–1267
20. Dexter F, Macario A (2005) Validity and usefulness of a method to monitor surgical services' average bias in scheduled case durations. Can J Anesth 52:935–939
21. Steers W, LeBeau S, Cardella J, Fulmer B (2004) Establishing a robotics program. Urol Clin N Am 31:773
22. Archer T, Macario A (2006) The drive for operating room efficiency will increase quality of patient care. Curr Opin Anaesthesiol. 19:171–176