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ORIGINAL ARTICLE

Gynaecological robotic surgery in an Irish setting—cost analysis

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Abstract Robotic surgery is associated with reduced hospital stay compared with open surgery. While the initial outlay is expensive, the increased number of patients amenable to this minimal access approach compared with conventional 'keyhole surgery' has the potential for financial savings. Our aim was to show the cost per surgery and the potential for savings with increased caseload and reduced hospital bed stay. A cost analysis was performed incorporating an audit of robotic surgery over the initial 3 years. This was performed using prospectively acquired data completed after each robotically assisted case. Depreciation and maintenance on the robot accounted for an outlay of €260,000/annum. Due to the learning curves and hospital constraints, in year 1, an average of 1.5 cases were performed per week at a cost of €5,980/case, this cost reduced to €4,250 over the next 2 years with an increase to 2.4 cases/week. We projected that if maximum usage of nine cases/week was achieved the cost would reduce to €2,523/case. In 2010, 36 % of all hysterectomies were performed robotically. The average length of stay for robot-assisted cases was two nights compared to six to eight nights for open hysterectomy. The robotic approach is associated with savings of approximately €201,933/year compared with a similar tertiary referral hospital in Ireland with no robot. Purchasing a robot is costly but associated with greater cost savings when reduced length of stay is accounted for. Furthermore, maximisation of robotic use further decreases the cost per case.

Keywords Robotic surgery · Gynaecology · Cost analysis

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Background

Surgery is an evolving science, aiming to improve patient outcome and reduce complication rates. Within the last 50 years, machines have been made to mimic human actions in order to perform specific tasks rather than to entertain and amuse. Furthermore, within the last 20 years, robotic technology has been applied to the practice of surgery. The goal of this technology has not been to replace the surgeon, but rather to enhance his or her performance with highly advanced tools [1]. At present, Intuitive Surgical® market the da Vinci® Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA, USA), the only commercially available robot system with Food and Drug Administration (FDA) approval for use in gynaecology. Since gaining FDA approval in 2005, the role of the robot has increased with many traditional procedures now being performed with robot assistance. Within the gynaecological surgery setting, the robot has been used successfully for simple and radical hysterectomy, pelvic lymphadenectomy, tubal surgery, myomectomy, sacrocolpopexy/hysteropexy and interval cervical cerclage [2]. As with all new techniques, there is a learning curve associated with robotic surgery, this is divided into three stages: (1) the initial phase, (2) the plateau phase and (3) the mastery phase [3]. Each phase has been shown to be associated with a number of procedures performed. However, the learning curve varies from surgeon to surgeon and is influenced by the complexity of the case. In the study by Bokari, the initial phase is associated with the first 15 cases performed and the subsequent 10 cases are the plateau phase where the surgeon becomes more proficient with the techniques required prior to progressing to the mastery phase. During the mastery phase, the technical difficulty of the cases performed increases and accounts for the final 23 cases [3]. With specific regard to gynaecological surgery, the learning curves reported range 50 cases for benign hysterectomies [4] to 10 cases for sacrocolpopexy [5]. This should be borne in mind when conducting cost analysis involving theatre times and caseloads per day.

New technology comes with an economic burden for the healthcare system. This increased initial outlay cost is often offset by the benefits to the patient in terms of reduced hospital stay, blood transfusion and a reduction in complications. For the surgeon, there is the benefit of shortened operating times, an ability to perform more complex surgery using a minimally invasive technique [5]. It is therefore important for the hospital and the health system within each country utilising the new robotic technology to have a clear understanding of the costs associated with the adoption and implementation of this new technology. With increasing financial austerity, even more emphasis is being placed on cost reduction within the health sector.

The Cork University Maternity Hospital (CUMH) is a tertiary referral centre, which treats both benign, urogynaecological and oncology patients. The da Vinci® Surgical System is located in the purpose-built laparoscopic theatre, which is dedicated solely to gynaecological surgery. The aim of this study was to assess the initial cost of purchase and set up for the programme, the running costs and the cost benefits for the first 3 years of the programme, which commenced in 2008. We also endeavoured to implement a strategy of cost reduction within our hospital setting.

Materials and methods

Over the 3 years (July 2008–May 2011) since instigating the robotic programme in our unit, a prospective record was kept of surgical times, including setup time, docking time, anaesthetic time, operating time and recovery time. For each case, the procedure, surgeon, complication/conversion rate and indication were all recorded. Demographic details of each patient were recorded. A total of 281 cases were performed predominantly by three surgeons, with a further two surgeons records included in the data, these surgeons were closely supervised by the more experienced surgeons. The procedures performed included: benign and radical hysterectomy, sacrocolpopexy/hysteropexy, adnexal surgery, myomectomy and interval cervical cerclage.

Data was recorded on the costs generated in theatre including staff pay, surgical instruments: disposable, reusable and robot specific. Furthermore, the cost of procedure-specific instruments was also recorded. A cost model was set up to analyse the cost per operation and allow financial adjustments to be made to assess the cost implications of increasing caseloads. The robot purchasing cost, maintenance and depreciation were derived from hospital specific figures. The depreciation was valued over 10 years based on the life span of the robot. Using the Health Service Executive (HSE) Ready Reckoner 2011, a specific cost per night hospital stay was recorded and a weighted average used per case based on the diagnosis-related group.

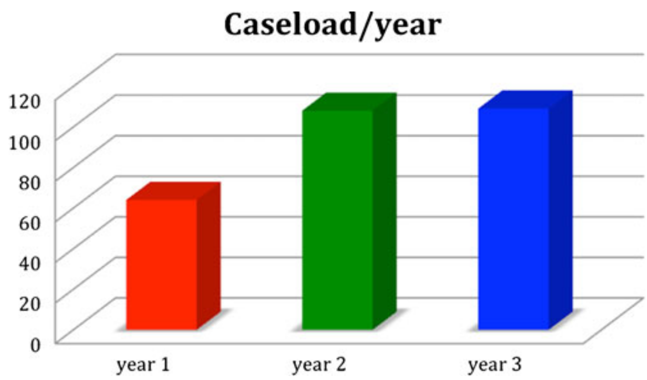

Fig. 1 Caseload per year

Findings

Two hundred and eighty one robotic procedures were performed by five surgeons from July 2008–May 2011 in our unit. The breakdown of cases was as follows: 76 % of cases were hysterectomy (simple and radical)±adnexal surgery, 18 % of cases were sacrocolpopexy/hysteropexy and the remaining 6 % were made up of interval cervical cerclage, myomectomy and endometriotic surgery (Fig. 1).

The cost of purchasing the da Vinci® Surgical System in 2008 was €1.35 million, with a current residual trade-in value of €800,000. The life expectancy is quoted as 7–10 years; however, many of the original systems in other units are still functioning 12 years since being commissioned. The maintenance contract is €125,000/year with an 'as new' policy. This incorporates all service and repair costs of the robot. Within the HSE, depreciation on machinery is

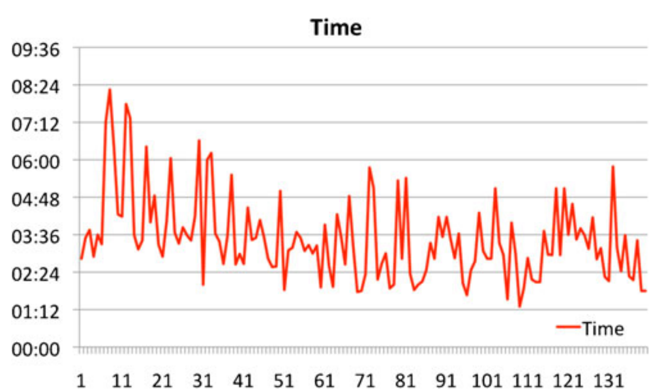

Fig. 2 Operative times over the course of the study for surgeon A

Table 1 The operative times per year of programme

	Operations/week	Mean in-theatre time per surgery type			Range of time
		Overall	Hysterectomy	Sacrocolpopexy	
Year 1	1.4	4:25	4:26	4:01	2:40–9:30
Year 2	2.3	3:11	3:24	3:01	1:50–5:45
Year 3	2.4	3:04	3:10	2:56	1:18–5:39

10 % straight line giving an annual cost of €135,000 based on a 10-year life expectancy. The total cost for maintenance and depreciation per annum is €260,000. Furthermore, the operative sets, including trocars and light cables cost €6,418. Four sets were constructed to allow time for sterilisation. The initial expenditure includes the cost of disposable trocars for the camera and the assistant (€94.78 per operation). Instrument costs varied according to the operation performed, as different instruments were required to perform the operation. The instrument cost was then assessed by type of operation—the sacrocolpopexy/hysteropexy cost €1,612 while all other operations cost €1,979 (Appendix A).

The surgical learning curves were evaluated and a per-year breakdown of procedures performed analysed (Fig. 2). As expected, the number of operations performed per week increased per year and the operative time decreased (Table 1). The CUMH is a training centre and during this period, three specialists registrars were trained using the system to the level of performing simple hysterectomies 'unassisted'. Furthermore, a recognised gynaecological robotic fellowship was commenced and the first graduate completed their training in the 2010. The instrument cost per annum based on caseload was calculated (Table 2). Using these figures, we calculated an average cost per operation, which incorporated the depreciation and maintenance costs. This overall cost decreases with increased caseload per year.

Using our cost model to calculate, the cost per operation if the caseload increased to a maximum of nine cases per week. In so doing the cost reduced from €4,250 to 2,523.

We analysed the cost benefit with regard to length of stay comparing open midline, lower transverse, laparoscopic, vaginal and robotic cases in our centre where the length of stay was eight (5–18), six (3–14), 3 (1–5), three (1–5) and two (0–4) nights, respectively. We then compared our hysterectomy caseload for 2010 to that of another tertiary referral teaching hospital in Ireland with similar inpatient capacity but no facility for robotic surgery. As expected, there were similar rates for vaginal hysterectomy at 45 % in both units, the reference unit performed more laparoscopic hysterectomies (20 vs. 5 %), and our unit performed fewer hysterectomies via the abdominal approach (14 vs. 35 %). We performed 36 % of our hysterectomies using the robot. When we compared our hysterectomy figures for 2009 to 2010, we found the abdominal approach had reduced from 24 to 10 % (Fig. 3a and b). This reduction in open cases is associated with a reduction in cost for length of stay. Using the HSE Ready Reckoner 2011, it was calculated that the weighted average based on the case mix treated for one night of stay is €534.19. We predict if the rate of open procedure falls by a further 10 % as it did between 2009 and 2010, we would save €201,932 due to bed day reduction (Table 3a and b).

Comments

Health Technology Assessments assess the clinical benefits of the new technique in relation to the cost of its implementation. Two recent health technology assessments (HTA) concluded that robot-assisted surgery is an emerging technology that could be promising in ideal circumstances and given adequate training and experience of the surgical team performing the interventions [6] and may have a significant impact on many clinical outcomes in patients undergoing prostatectomy, partial nephrectomy or hysterectomy; however, benefits vary between indications [7]. Robotically performed surgery is costly compared with open and laparoscopic approaches. The investment made in acquiring this technology is significant, and institutions that choose to

Table 2 Cost per year for robotic instruments

	Hysterectomy Total number/year	Sacrocolpopexy Total number/year	Instrument cost Hysterectomy	Instrument cost Sacrocolpopexy	Total cost/year
Year 1	57	7	112,845.75	11,287.50	124,133.25
Year 2	89	19	176,197.75	30,637.50	206,835.25
Year 3	83	26	164,319.25	41,925.00	206,244.25

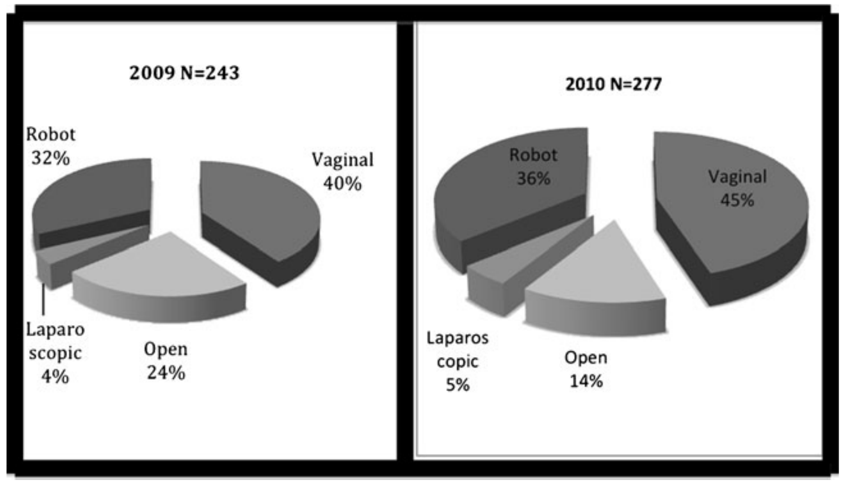

Fig. 3 Comparison of mode of hysterectomy in CUMH in 2009 and 2010

adopt it should make efforts to monitor its costs and outcomes in order to maximise cost-effective use within their own centre. To decrease costs, centres should maximise caseloads, consider keeping the robot operational for longer durations if possible, and use the technology for multiple indications, particularly those with greater potential impact on important patient outcomes and savings on institutional costs [7]. Furthermore, the increased bed usage and throughput of patients would decrease waiting lists and eliminate the need for national treatment purchasing fund to purchase treatment in private hospitals for these patients. The knock-on effect is to reduce the number of gynaecological emergency admissions by patients on long waiting lists. There would also be social savings such as reduced post-operative sick leave and earlier return to work.

In 2009, the American Congress of Obstetricians and Gynecologists released a statement recommending vaginal hysterectomy as the approach of choice for benign hysterectomies due to reduced operating times when compared to the laparoscopic approach [8]. However, they note that laparoscopic surgery is an alternative where vaginal hysterectomy is not feasible or indicated. Increasing the rate of vaginal surgery decreases the cost of surgery compared to the open approach due to reduced length of stay. Consideration must be given to the fact that not all surgeries are amenable to the vaginal approach. Our figures showed that during 2009–2010, our vaginal hysterectomy rate increased from 40 to 45 % in association with the decrease in open hysterectomies. Our rate of vaginal hysterectomy was equal to that of another tertiary referral unit in Ireland. However, as a tertiary referral centre providing oncology care, the robotic approach allows complicated and radical hysterectomies be performed using a minimal access approach. Our rates of open hysterectomy were almost three times lower (14 vs. 35 %) when compared to a similar sized tertiary referral centre in Ireland where robotic surgery is not available.

In conducting a cost analysis, there are direct, indirect and hidden costs, which need to be addressed. In this study, staffing costs were the same for all modes of surgery as irrespective of how and who performed the operation the same staff were employed to be present in theatre during normal working hours in the public sector. However, there is a cost saving potential in terms of staffing when using the da Vinci® Surgical System as a surgically trained assistants are not required, the scrub nurse can be trained to assist thus saving on salaries and leading to the redeploying of staff to

Table 3 Savings due to bed day reduction between 2009 and 2010

Types of hysterectomy	Number of cases/year	Average length of stay	Bed nights	Total cost per operation type	Accumulative cost
Predicted cost benefit for length of stay in CUMH (bed=534.19/night)					
Vaginal (45 %)	126	3	378	201,923.82	
Open (5 %)	14	6	84	44,871.96	
Laparoscopic (5 %)	14	3	42	22,435.98	
Robotic (45 %)	126	2	252	134,615.88	403,847.64
Predicted cost for length of stay in unit without robotic surgery (bed=534.19/night)					
Vaginal (45 %)	126	3	378	201,932.82	
Open (35 %)	98	6	588	314,103.72	
Laparoscopic (20 %)	56	3	168	89,743.92	605,780.46

another area. The central sterile supply department may require updating and new equipment and training required for staff dealing with the robot equipment, and finally the existing timetables for theatre may need to be adjusted to maximise robotic use. With regard to the indirect costs, many relate to the provision of the new programme including administrative staff, a programne co-coordinator/manager and data collection. The administration duties are conducted by current employees and data collection is performed by the theatre staff and the medical staff.

Historically, in Ireland, the length of stay has been higher than that of other European countries. While we are not aware of any studies that have examined factors which may influence the increased length of stay, possible influences include: reduced respite care, reduced provision for domiciliary visit by the public healthcare team and patients' expectations. To reduce the impact of patient and family expectation on length of stay, all patients are now counselled in the outpatients department as to their expected length of stay thereby reducing any misunderstanding by the patient and family regarding discharge days. Barnett et al. [9] used three different costing models and showed that laparoscopy was the least expensive surgical approach for the treatment of endometrial cancer. The robot is less costly than abdominal hysterectomy and is most economically attractive if disposable equipment costs can be minimised. When laparoscopic hysterectomy was compared with robot-assisted hysterectomy in terms of cost and clinical outcomes, there was no significant differences with regards to perioperative and postoperative events, but there was an increased per-case cost for the robot [10]

Conclusion

From the results of our study, we concur that the initial expenditure for the da Vinci® Surgical Systems is substantial, it is associated with the potential cost benefits of reduced length of stay, from 6 to 8 days for an open hysterectomy to 2 days for a robot-assisted hysterectomy. We are currently looking at outcome measures such as patient perception of recovery, with provisional results showing low post-operative pain scores and the majority of patients performed simple household chores within a week of surgery and 50 % were driving within 4 weeks of surgery. In this study, we have shown that maximising the caseload to nine cases per week reduces the overall cost of the operation, which would involve increasing our current caseload threefold. Based on these figures, a throughput of 450 robot-assisted operations would be required. In 2010, a total of 155 robot-assisted operations were performed, which would leave a shortfall of 300 cases. Clearly reducing the number of unwarranted open procedures would not increase the caseload to the required figure. Therefore, provision would need to be made to optimise the workload by opening the robot up to other specialties where the robot-assisted surgery has shown to be effective.

A recently published Irish HTA looked at the financial implications of robot-assisted surgery [11]. Using an economic model which was restricted to the HSE perspective and only incorporating direct costs, they showed the incremental cost of robot-assisted surgery (over the robot lifespan) if used for hysterectomy alone is €3,019 (95 % CI: €2,582–3,733), assuming a steady state volume of 300 cases per annum. However, when used for a combination of prostatectomy and hysterectomy procedures, it is €2,864 (95 % CI: €2,384–3,587). As expected, they found the increased cost of robot-assisted surgery was primarily due to the additional costs associated with the specific surgical equipment, purchase and maintenance and the cost of theatre staff due to longer operative times. They believe the costs are only partially offset by savings associated with shorter inpatient stays. Furthermore, based on the steady state volumes used in the model, use of one robot to assist surgery compared to standard surgical techniques will reduce the annual number of bed days by 565 days (95 % CI: 422–721) if used for hysterectomy alone and 558 days (95 % CI: 417–697) if used for a combination of prostatectomy and hysterectomy. Also, increasing the annual volume of cases per robot reduces the incremental cost of robot-assisted surgery, as does extending the lifespan of the robot. Interestingly the HTA concluded that the number of days to return to normal activity appears substantially shorter after robot-assisted surgery compared to open surgery and as such, robot-assisted surgery may offer a significant societal benefit.

Quality Adjusted Life Year (QALY) assessments are a standard to evaluate the outcomes of healthcare expenditure [12]. They offer a measure by which to ascertain which patient to treat and which treatment to use based on the quality of life benefit received by a certain form of intervention. It was not possible to assess the QALY for robotic surgery during our study and to date we are not aware of any studies which report this exercise. However, it would be beneficial to have a set of parameters by which to assess robotic outcomes further.

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Declaration of interest Matthew Hewitt has received travel bursaries to attend educational meetings. He acts as a surgical proctor for Intuitive. All financial reimbursement from the company is placed in the department's research fund. Barry O'Reilly is a proctor for Intuitive. All financial reimbursement from the company are placed in the departments' research fund. The Cork University Maternity Hospital is an Intuitive recognised epicentre for robotic surgical training. All funds received from this are placed in the department's research fund.

Appendix A

Cost as per Cork University Maternity Hospital 2008

Table 4 Initial purchase cost and yearly cost

Product	Company	Model	Cost per unit	Life expectancy (years)	Maintenance	Residual value	Deprciation	Cost per year
Da Vinci Robot	Intuitive	Si Dual	2.1 m	7–10	165,000			
		Si Single	1.6 m	7–10	140,000			
		Cork model	1.35 m (2008)	7–10	125,000	800,000	10 % straight line	125,000+135,000=260,000

Table 5 Instrument cost per type of surgery

Product	Company	Quantity/box	Cost per unit	Box quantity	Cost per box	Vat rate (%)	Total cost per unit	No of units per procedure	Hysterectomy	Sacrocolpopexy
All in One 1032P	3M	1	29.18	10	291.80	21	35	1	35	35
Robot Drapes	Intuitive	1	234.00	5	1,170.00	21	283	1	283	283
Endo Wrist Instrument	Intuitive	10 uses/item								
Pro-grasp			220.00	1	2,200.00	21	2,662.00	1	266.20	266.20
Maryland Forceps			2,700.00	1	2,700.00	21	3,267.00	1		326.70
PK Dissector			2,900.00	1	2,900.00	21	3,509	1	350.90	
Monopolar Scissors			3,200	1	3,200	21	3,872	1	387.20	387.20
Fenestrated Bipolar Forceps			2,700	1	2,700	21	3,267	1	326.70	
Suture Cut Needle Holder			2,400	1	2,400	21	2,904	1	290.40	290.40
Cover for Scissors			20	10	200	21	24	1	24	24
Gyrius Cable		20 uses/item	270	1	270	21	327	1	16.35	
Valleylab Black Mono polar Cable		Reusable	184.70	1	184.70	21	223	1	0	0
Valleylab Bipolar Disposable Cable		1	2.40	50	120.00	21	3	0		
SCD Sleeve	TYCO		22.00	5	110.00		22	0		
Total cost									€1,979.75	€1,612.50

Table 6 Cost for each operative set

Product	Company	Quantity/box	Cost per unit	Box quantity	Cost per box	Vat rate (%)	Total cost per unit	No units per procedure	Total cost
Disposable Trocar		1	39.17	6	235.02	21	47.39	2	94.78
Metal Trocar		1	550	1	550		550	3	1,650
Obturator		1	550	1	550		550	2	1,100
Scope Target		1	500	1	500		500	1	500
Camera Adaptor		1	950	1	950		950	1	950
Camera Arm Adaptor		1	950	1	950		950	1	950
Light Cable		1	950	1	950		950	1	950
Monopolar Cord		1	184.70	1	184.70	21	223.49	1	223.49
									6,418.27

Table 7 Cost per operation depending on caseload

	Average cost/operation	Average operation/ per week	Maintainence/week	Maintainence/case	Depreciation cost	Ave cost/per operation
Year1	1,943.28	1.4	2,717.40	1,941.00	2,934.80/2,096.30	5,980.58
Year2	1,913.65	2.3	2,717.40	1,181.50	2,934.80/1,276.00	4,371.15
Year3	1,895.29	2.4	2,717.40	1,132.25	2,934.80/1,222.83	4,250.37
Projected figures						
	1,895.29	3	2,717.40	905.80	2,934.80/978.30	3,779.40
	1,895.29	6	2,717.40	452.90	2,934.80/489.20	2,834.40
	1,895.29	9	2,717.40	302.00	2,934.80/326.10	2,523.40

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