Cost Considerations for Robotic Surgery

James Kenneth Byrd, MD*, Rebecca Paquin, MD, DMD

KEYWORDS

• TORS • Transoral • Robotic • Surgery • ENT • Otolaryngology • Economic • Cost

KEY POINTS

- Transoral robotic surgery (TORS) is rapidly becoming a more commonly used therapeutic and diagnostic tool.
- Cost-effectiveness analysis is complex and should include evaluation of both economic impact as well as impact to the health state.
- On analysis of current data, TORS seems to be cost-effective when patient selection is appropriate.

INTRODUCTION

Robotics is growing steadily across surgical disciplines.[1–3] The demand for robotic surgery has increased significantly since its advent, creating a market worth of more than $3 billion in 2014, projected to exceed $20 billion by 2021. The da Vinci surgical robot (Intuitive Surgical, Sunnyvale, CA) is the most commercially successful robotic surgical platform to date.[4] As of 2017, an estimated 2800 of 5500 hospitals in the United States own a da Vinci robot, with an estimated 644,000 robotic surgeries performed annually nationwide.[5]

Robotic head and neck surgery has transformed the management of benign and malignant diseases of the head and neck in slightly more than a decade. Before the advent of transoral robotic surgery (TORS), oropharyngeal squamous cell carcinoma (OPSCC) was typically treated with primary open surgical approaches or with primary chemoradiation therapy (CRT), leading to cosmetic deformities, toxicities, and deleterious impacts on oropharyngeal and laryngeal function. TORS as a primary treatment modality for tongue base squamous cell carcinoma was first described in the literature in 2006; this was followed by approval of TORS for both benign and malignant diseases of the head and neck by the US Food and Drug Administration in 2009.[6,7] TORS has since developed as an option that preserves optimal patient function and

Otolaryngology – Head and Neck Surgery, Medical College of Georgia, Augusta University, 1120 15th Street BP 4132, Augusta, GA, USA
* Corresponding author.
E-mail address: ken.byrd@augusta.edu

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long-term quality of life.[3,8–11] Many studies show that TORS is an effective diagnostic and therapeutic oncological tool.[3,12–16] However, to gain a comprehensive understanding of outcomes, the cost implications of TORS must also be considered, because some investigators have implicated robotic technology in driving up health care costs.[17]

Aggregate surgical expenditures are expected to grow from $572 billion in 2005 (4.6% of US gross domestic product [GDP]) to $912 billion (in 2005 dollars) in the year 2025 (7.3% of US GDP). Both national surgical and overall health care expenditures are expected to grow by approximately 60% during the period 2005 to 2025. These trends have been in place since World War II, and the increase has been attributed to generously rewarded advances in medical and surgical technology, an insurance system that obscures the true cost of health care, the increasing age of the population, defensive medicine, an increasing number of available services, and so-called free-rider access to the US health care system provided to anyone who enters the system as an emergency. Per capita GDP growth in the United States is relatively flat. Based on these assumptions, by 2025, surgical health care expenditures will account for one-fourteenth of the entire US economy.[18]

Economic evaluation in health care is complex, given the number of variables affecting cost and measurement. Costs vary widely from institution to institution, among regions and countries, and based on whose perspective costs are being analyzed (payer, patient, or society). Furthermore, indirect costs such as lost time, transportation, childcare, and other factors are not well captured by looking solely at the bottom line. According to the Panel on Cost Effectiveness in Health and Medicine, a group convened by the US Public Health Service in the mid-1990s, economic evaluation of interventions and technology should analyze both health care expenditure and its impact, ideally, to the health state.[19] In general, Smith and Rudmik[20] outlined the principles and challenges of cost collection and analysis in a 2013 article in *Otolaryngology–Head and Neck Surgery*. The present article summarizes the current literature regarding cost and cost-effectiveness of robotic surgery in the head and neck.

DISCUSSION

Few articles to date have objectively analyzed the cost-effectiveness of robotic surgery in the head and neck. Some have criticized robotic surgery because of the high initial investment to purchase either of the 2 widely available systems. The initial cost of the da Vinci robot with the 4-arm system and software upgrades is approximately $1.5 million. The service contract for the robotic surgical system is approximately $150,000 per year.[5,21] However, the robot is typically a capital investment made by the hospital, shared among multiple services, and is most relevant in the setting of starting a new robotic program with limited use. The additional cost per TORS procedure using the da Vinci system is approximately $500 for disposable equipment.[22] The initial cost of da Vinci's primary competitor, the Flex robotic system (Medrobotics, Raynham MA), is estimated to be approximately $1 million. At this time, detailed cost analyses are only available for the da Vinci system.[23]

The literature generally indicates that the balance is in favor of TORS when all costs are considered. Multiple institutional series have shown that TORS is associated with a short hospital length of stay (LOS) and low morbidity and mortality.[24–28] In a 2018 literature review by Othman and McKinnon,[29] which focuses on the financial impact of TORS, the investigators found that TORS saved an average of $8355 per procedure and 1.8 hospital days compared with other surgical approaches for OPSCC. Motz

and colleagues[30] showed that TORS is associated with a shorter LOS as well as lower hospital-related costs than non-TORS procedures. Hammoudi and colleagues[31] performed a comparison of TORS with open procedures and concluded that the robotic technique should result in both lower morbidity and lower treatment cost with no increase in complication rate and equivalent oncologic control. Similarly, Chung and colleagues[7] found that TORS for partial pharyngectomy and partial glossectomy for the base of tongue was associated with shorter hospital LOSs, lower charges, and lower costs than open procedures. However, the investigators did find that TORS was inferior to open surgery in cost measures for partial glossectomy of the anterior tongue. This difference indicates that the cost benefit may be limited by anatomic subsite. Dombrée and colleagues[32] compared TORS, transoral laser microsurgery (TLM), and open surgery for partial and total laryngectomies using activity-based costing, a cost-accounting system that allocates resource costs to products using a multistep allocation procedure assessed by activity consumption. Although the investigators found shorter operating times for TORS compared with TLM and open surgery, they nevertheless found an increased cost with TORS. This increased cost was still the case even when the investigators decreased the equipment depreciation and maintenance costs to zero and simulated a doubling of the annual TORS case load. They were able to attribute most of the cost associated with TORS to robot-specific activities, such as installation of the robot, sterilization of the robotic instruments, and external maintenance. These activities are different from TLM and open procedures, where the cost distribution is predominantly determined by personnel cost.[32]

As an extension of TORS for OPSCC, there has been interest in using lingual tonsillectomy to identify the primary site in cervical unknown primary (CUP). In a retrospective study that included a basic effectiveness measure, Byrd and colleagues[33,34] evaluated the incremental cost-effectiveness ratio (ICER), a measure of cost-effectiveness analysis comparing costs of 2 different procedures to localize the primary tumor in CUP, using standardized costs to compare examination under anesthesia (EUA) with tonsillectomy with sequential TORS base of tongue resection. The ICER for TORS base of tongue resection after EUA with tonsillectomy failed to localize the primary was $6208 per primary localized. Although this cannot be extrapolated to dollars per quality-adjusted life year (QALY) because of the unknown impact of limiting the radiation field, the investigators concluded that TORS lingual tonsillectomy after failed EUA with tonsillectomy is a modest expenditure.

Whether robotic surgery or nonsurgical treatment is more cost-effective is controversial. Simply considering financial data, TORS seems to be more cost-effective, provided that the number of treatment modalities is the same or lower. Moore and colleagues[35] retrospectively reviewed collections data for government and private payers treated for OPSCC at 2 academic institutions. Transoral surgery (TOS) alone as treatment of OPSCC had the lowest overall cost over a 90-day time frame compared with TOS with adjuvant radiation therapy (RT), TOS with adjuvant CRT, and primary CRT. In agreement with these findings, Tam and colleagues[36] performed a case control study comparing charges and costs for 15 stage II to IVa (AJCC seventh edition) patients with OPSCC treated with TORS versus 15 matched patients treated with CRT at a single institution over 1 year. For selected stage II to IVa OPSCC, frontline TORS was 22% less expensive than upfront CRT 4 months after the initial treatment and 14% lower 1 year after treatment. A significant number of patients were treated with cetuximab, rather than cisplatin, which contributed to the higher cost of treatment. Neither of these studies incorporated effectiveness, and Tam and colleagues[36] acknowledge that their small series may be subject to selection bias.

To accomplish cost-effectiveness analysis as recommended by the Panel on Cost Effectiveness in Health and Medicine,[19] costs are compared and utility values are incorporated to generate dollars per QALY in an ICER. Society's willingness to pay, which determines whether an intervention or technology is cost-effective, is controversial and has historically ranged from $50,000 to $100,000 per QALY in the literature, but has been suggested to be even as high as $200,000 per QALY.[37] Utility values range from 0 (death) to 1 (perfect health), representing a health state at a point in time. de Almeida and colleagues[38] published utility values generated from 50 healthy subjects and 9 experts via the Standard Gamble technique and visual analog scale in 2014. TORS-based treatments led to higher utility scores than radiation-based treatments. These values were subsequently incorporated into several cost-effectiveness analyses using decision trees and Markov models for TORS.

The 4 cost-effectiveness analyses have disparate findings based on model parameters and assumptions made. de Almeida and colleagues[39] found a cost saving of $1366 and an increase of 0.25 QALYs per case when using TORS as treatment of early T classification OPSCC compared with CRT over a 10-year time horizon. Conversely, there are 3 studies that indicate nonsurgical therapy as the more cost-effective option.[40–42] Rodin and colleagues[40] found that, under base case assumptions, TORS was associated with moderate gains in QALYs and an ICER of $82,190/QALY gained. This ICER was most sensitive to need for adjuvant therapy, cost of late toxicity, age at diagnosis, disease state utilities, and discount rate. Accounting for joint parameter uncertainty, RT had a higher probability than TORS of being the more cost-effective option (54% vs 46%). Of note, this study compared RT versus TORS alone, or with postoperative RT or CRT, but did not include definitive CRT or salvage surgery for radiation failure in the analysis. Similarly, Rudmik and colleagues[42] found that TORS is 42% likely to be cost-effective, with an ICER of $165,300 per QALY because of being approximately $5000 more costly and associated with only a gain of 0.03 QALYs. Sher and colleagues[41] analyzed T1 to T2, N2 OPSCC using regional cost data from the Chicago Medicare payment schedule and also found that CRT was the dominant strategy; this analysis was most sensitive to the likelihood of adjuvant CRT after TORS (61% in the base case) and differences in utility. In addition, the base case patient age in this study was 65 years, which could potentially limit some of the long-term benefits in quality of life for the theoretic patients who were able to avoid chemotherapy.

A consideration incorporated into the analysis by Sher and colleagues[41] is that staged neck dissection is associated with increased cost.[41] LOS, anesthesia and operative costs, and undiscounted work relative value unit compensation account for the increased direct costs. Frenkel and colleagues[43] reviewed 425 cases of adults undergoing TORS with staged versus concurrent neck dissection and found that there was no significant difference between the rate of adverse events, including inpatient complications, need for additional procedures, and readmissions, but there was a significantly shorter LOS for concurrent procedures. Clinicians must therefore weigh the increased cost associated with staged procedures versus patient benefit.

A major consideration for economic evaluation of robotic surgery is that cost-effectiveness of TORS varies greatly based on the need for adjuvant therapy.[39] Although patients who undergo primary TORS may be less likely to receive postoperative CRT than those treated with other surgical approaches, a review of the National Cancer Database (NCDB) indicates that 20% of patients treated with TOS had positive margins, thereby meeting indications for CRT.[30,44] Another NCDB study suggests that surgeons are improving in patient selection, because the percentage of patients receiving trimodality therapy decreased from 23.7% to 16.9% and was largely driven by extranodal extension.[45] Ultimately, selecting patients who are amenable to

achieving negative margins and are unlikely to have extranodal extension is the most important factor in making TORS cost-effective, although predicting the latter based on imaging can be problematic.[46,47] In addition, selecting younger patients who are expected to survive longer without disease benefit makes the models more cost-effective via their higher utility values (ie, quality of life).[40]

Ultimately, prospective clinical trials may provide better evidence of the economic impact of head and neck robotic surgery. The Oropharynx: Radiotherapy vs Transoral Robotic Surgery (ORATOR) trial, a phase 2 trial comparing TORS with adjuvant therapy and CRT in 68 patients recently published its early results with 1-year follow-up; with longer follow-up, it may provide some information about the relative cost-effectiveness of the 2 strategies.[48] The Eastern Cooperative Oncology Group ECOG-E3311 phase 2 surgical trial for early stage human papilloma virus–positive OPSCC, having completed enrollment with 511 patients, will provide economic and quality-of-life data for patients treated with surgery with and without adjuvant treatment in the near future. However, as previously noted by Barber and Thompson,[49] the analysis and interpretation of cost data from clinical trials must be approached with appropriate statistical techniques, because a review of the literature indicates that inappropriate conclusions based on economic evaluation of trials are common.

SUMMARY

The use of robotic surgery in otolaryngology–head and neck surgery, as well as in other specialties, is increasing, as is the market worth of the predominant robotic surgical platforms. There seems to be a trend toward primary surgical management of OPSCC since the advent of TORS, because TORS has developed as an effective diagnostic and therapeutic tool. A full assessment of robotic surgery is not complete without an assessment of cost-effectiveness; however, evaluation of cost in health care is complex. Despite the high cost of ownership of the surgical robotic platform, TORS seems to be largely cost-effective for oropharyngeal surgery, but depends heavily on patient selection.

CLINICS CARE POINTS

- TORS seems to be equivalent to CRT in oncological outcomes for OPSCC and may provide improved functional outcomes based on retrospective studies and limited prospective data.
- The initial cost of a robotic system is a significant capital investment for the hospital, but should not weigh heavily in economic evaluation because it is a shared fixed cost among multiple services, rather than a variable cost.
- To date, TORS generally seems to be a cost-effective method of treatment of OPSCC, provided that patients are appropriately selected so that trimodality therapy is minimized.

DISCLOSURE

The authors have nothing to disclose.

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