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Is There Room for Microsurgery in Robotic Surgery?*

Existe espaço para a microcirurgia na cirurgia robótica?

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Abstract

Robotic surgery opened a new era of minimally-invasive procedures, through its improved precision, elimination of tremors, greater degrees of freedom, and other facilitating aspects. The field of robotic microsurgery showed great growth in recent years in particular, since robotics offers a potentially-ideal configuration to perform the sensitive manipulations required in microsurgery. We conducted a systematic review to assess the benefits of robotic surgery and its contributions to microsurgery, comparing it with other surgical techniques used in patients of all age groups. We assessed 25 articles found in the PubMed and Cochrane databases using the terms '*robotic surgery*' AND *microsurgery*, with a filter for studies published in the last five years, and studies conducted in humans and published in English or Portuguese. We concluded that there is plenty of room for robotic surgery in microsurgery, such as in male infertility procedures, neurological microsurgery, ocular and otological surgeries, and transoral, hepatobiliary, microvascular, plastic and reconstructive surgeries.

Keywords

- ► robotic surgical procedures
- ► microsurgery
- ► minimally-invasive surgical procedures

Resumo

A cirurgia robótica abriu uma nova era de procedimentos minimamente invasivos, por meio da sua precisão, da eliminação dos tremores, e dos maiores graus de liberdade e demais aspectos facilitadores. O campo da microcirurgia robótica apresentou grande crescimento nos últimos anos em especial, uma vez que a robótica oferece uma configuração potencialmente ideal para realização das manipulações delicadas exigidas na microcirurgia. Assim, conduzimos uma revisão sistemática com o objetivo de avaliar os benefícios da cirurgia robótica e sua contribuição para a microcirurgia,

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Palavras-chave
- procedimentos cirúrgicos robóticos
- microcirurgia
- procedimentos cirúrgicos minimamente invasivos

comparando-a com as demais técnicas cirúrgicas utilizadas em pacientes de todas as faixas etárias. Foram analisados 25 artigos encontrados nas bases de dados PubMed e Cochrane utilizando os descritores *robotic surgery AND microsurgery* com filtro para os últimos cinco anos, e estudos realizados em humanos e publicados em inglês ou português. Concluímos que existe grande espaço para a cirurgia robótica na microcirurgia, como em procedimentos primários de infertilidade masculina, microcirurgia neurológica, cirurgias oculares e otológicas, cirurgia transoral, hepatobiliar, microvascular, e cirurgia plástica e reconstrutiva.

Introduction

The concept of robot-assisted surgery was proposed by military doctors during World War II, aiming to create a system to remotely control surgeries. However, it was not until 1994 that Phil Green designed a remote surgery operating system, which consisted of a console and a wireless control arm.[1] The last decade has seen robotic surgery become the standard in some specialties to perform minimally-invasive procedures.[2]

Robotic surgery has opened a new era of minimally-invasive procedures, with its improved precision, greater degrees of freedom (DOFs), superior three-dimensional (3D) vision, improved resolution, and elimination of tremors.[3] Urological, gastrointestinal, endocrine, cardiac and plastic surgeries are some of the examples of fields in which robotic surgery is more established.[4]

The most widely used robotic system is the Da Vinci Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA, United States), which currently uses high-definition (HD) 3D magnification with seven DOFs.[4] The Da Vinci robot consists of three elements: the surgeon's console, the patient-side cart with its articulated or swiveling arms, and the vision cart.[5] Thus, this system has the advantages of 3D stereoscopic vision, greater dexterity, in which the movements of the instruments are facilitated by articulated wrists enabling seven DOFs, greater accuracy, and faster mastery of endoscopy.[6] However, there are limitations to the system, such as size, as the robot components occupy considerable space, installation time, and high cost.[7]

One of the most common applications of robotics is in microsurgery, a unique field which requires the highest levels of precision for optimal results and high success rates.[3] There are initial applications such as transoral robotic reconstructive surgery,[8,9] nipple-sparing mastectomy (NSM) with immediate breast reconstruction (IBR) using prosthesis,[10,11] minimally-invasive harvest of pedicled or microsurgical muscle flaps,[12–14] and robot-assisted microsurgery.[3,15]

Recently, the first clinically available surgical robot for microsurgery was developed, called MUSA (MicroSure, Eindhoven, The Netherlands). Acting on the stabilization of movements, the MUSA robot filters out tremors and is easily maneuverable, and the preclinical tests confirmed the safety and feasibility of this robot in performing microsurgical anastomoses.[16,17]

It is undeniable that robotic surgery has a leading role today, with perspectives of its use in plastic surgery, for example, in which robots have a 3D reading system that can scan human faces and other parts of the body, quickly generating accurate models.[18] It has also been shown[19] that, in a center in which the learning curve has already been overcome, robotic surgery becomes cheaper than the equivalent open surgery for the treatment of endometrial cancer.

The biggest disadvantage is the high cost of purchasing and maintaining the equipment, a fact that may change in the future, with the increase in the number of procedures performed using the robot and the consequent reduction in the unit cost per operation.[20]

The need to accelerate the understanding of robotic surgery and microsurgery is currently extremely important.

The present study will analyze the literature on this topic in order to contribute to the choice of microsurgery in appropriate procedures. Furthermore, our conclusions can contribute to the new era of Medicine, in which robotic devices are considered great allies, with the objective of verifying the effectiveness of the results of the use of the robot in microsurgeries, to support the investment in it on the part of the hospitals, as well as evaluating minimally-invasive procedures in different reconstructive surgical fields.

In the present article, we conduct a systematic review and evaluate the benefits of robotic surgery and its contribution to microsurgery, comparing it with other surgical techniques used in patients of all age groups.

Methodology

On the PubMed and Cochrane databases, we performed a systematic review of the literature on robotic surgery and microsurgery based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The search terms used were *robotic surgery* AND *microsurgery*, and we applied a filter to studies published in the last 5 years (from 2015 to 2020) in English or Portuguese, and studies performed in humans. Furthermore, we included literature reviews, systematic reviews, meta-analyses, clinical studies, clinical trials, comparative studies, controlled or randomized clinical trials, multicenter studies, observational studies, case reports, and case series studies. Preclinical and unfinished studies were excluded from the review.

The research question was based on the Patient, Intervention, Comparison, Outcome (PICO) model. We included

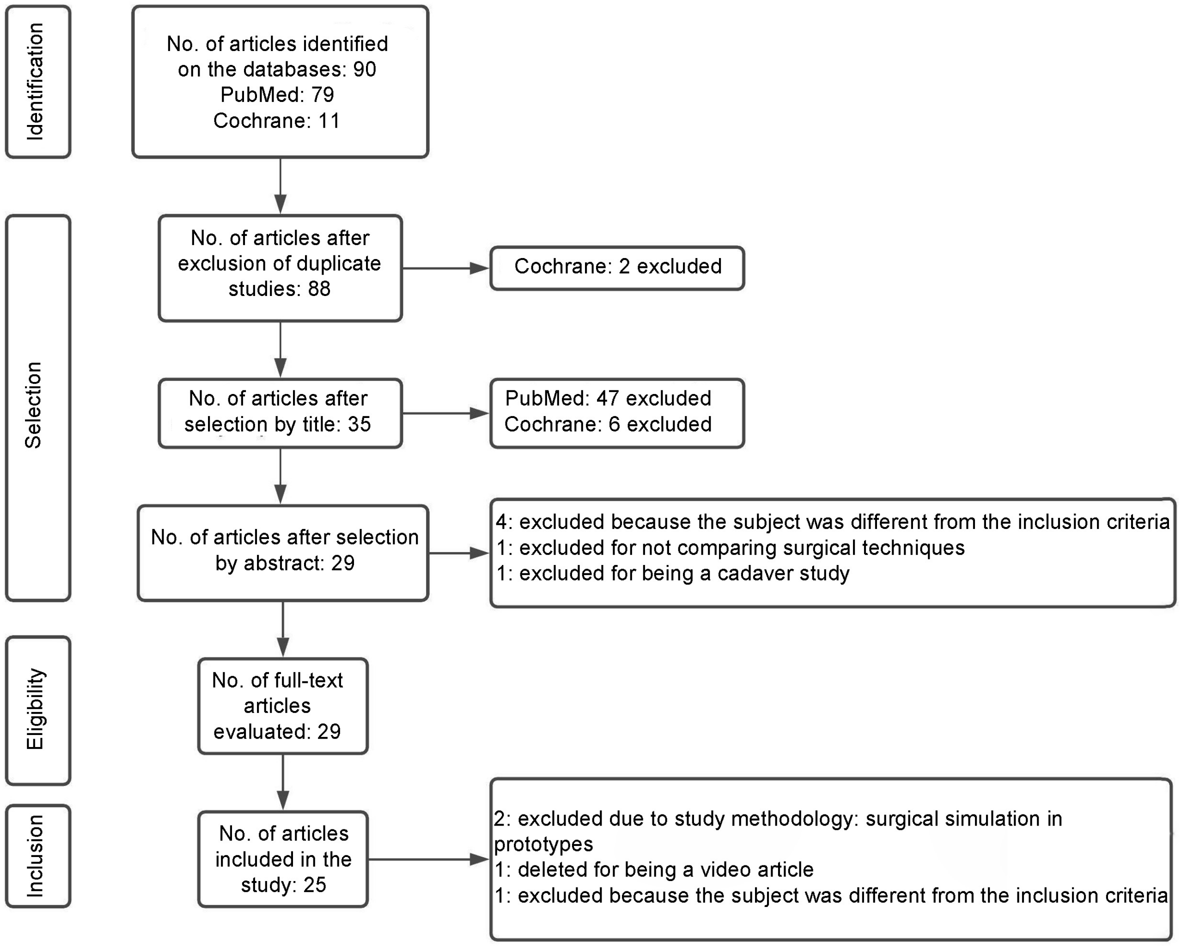

Fig. 1 Flowchart of the selection of articles.

patients of all age groups. The intervention analyzed was the use of robotics to perform microsurgery, comparing this technique with other methods. Finally, the outcome of interest was the benefits of robotic surgery and its contribution to microsurgery.

The analysis of the databases was performed independently and in pairs, as well as the selection of articles by title, abstract, and full-text reading. All decisions were compared, and differences that emerged were resolved by a third author. The results were recorded in a shared Excel (Microsoft Corp., Redmond, WA, United States) spreadsheet, and all duplicates were excluded.

The search, completed in January 2021, resulted in 90 articles found on the selected databases, and 2 of these were excluded because they were duplicates. After analyzing titles, abstracts and reading the full text, 25 articles were selected for the present review. A flowchart of the selection of articles is presented in ►**Figure 1**.

Results

Goto et al.[21] conducted an observational study to evaluate the benefits of iArmS, a system used in neurological microsurgery that supports the surgeon's arm weight. The evaluation parameters were the surgeon's level of fatigue, degree of tremor, and ease in performing the procedure. The authors[21] approved the system in all three assessments, stating that it enables the performance of an accurate and quality technique for microneurosurgery. Ibrahim et al.[3] also highlighted the applicability of robotics in neurosurgery, drawing attention to the Canadian NeuroArm robot, which assists in the performance of standardized techniques such as biopsy and microdissection.

Smith et al.,[22] in their review of the evolution and application of robotics in neurosurgery, concluded that this technology has brought several benefits. According to the authors,[22] robotics can be used for the treatment of brain tumors, spinal cord injuries, brain stimulation, and biopsies. In addition, the associated use of the robot and imaging methods resulted in higher levels of surgical precision. The authors[22] suggest that this technology tends to develop more and more, which will enable the performance of procedures not feasible through conventional surgery, as suggested by Roizenblatt et al.[23]

Kavoussi[24] compared vasectomy reversal performed through robotic surgery and microsurgery. The study did not demonstrate a statistically significant difference between the two methods regarding the effectiveness of the procedure. However, the author[24] suggests that robotic surgery is promising, being an extremely effective method in vasectomy reversal, as stated by Ibrahim et al.[3] Darves-Bornoz et al.[25] reviewed the application of robotics to each of the four primary male infertility procedures: vasectomy reversal, varicocelectomy, testicular sperm extraction, and spermatic cord denervation. For the authors,[25] although the robotic platform has been quickly adopted by other urological subspecialties, it is still not common among reproductive urologists, as the data examining the approach are sparse, and no studies have tried to rigorously check the results. While the use of robots offers potential benefits to treat male infertility, rigorous clinical trials are still needed.

Edwards et al.[26] performed a randomized clinical trial with the aim of comparing intraocular surgery to remove the retinal membrane through a robot-assisted technique and through manual surgery. The study[26] demonstrated that robotic-assisted surgery resulted in longer operative times, but fewer iatrogenic injuries and greater anatomical accuracy. Therefore, the authors[26] suggested that robotics is promising technology for ophthalmic surgery, as did Ibrahim et al.[3]. In their studies, Bourcier et al.[27] and Roizenblatt et al.[23] also came to this conclusion, emphasizing that robotic surgery manages to circumvent one of the main limitations of manual surgery: the surgeon's hand tremor. Roizenblatt et al.[23] stated that the guarantee of precision is of extreme importance in eye surgery, since minimal erroneous movements can result in permanent sequelae, such as blindness when injuring the retina.

The study by Roizenblatt et al.[23] also highlighted other possibilities of application of robotics in eye surgery, such as in the treatment of macular injury, diabetic retinopathy, and canalization of retinal veins. Furthermore, Bourcier et al.[27] reported the first case of pterygium removal with the DaVinci Si HD robotic system. The procedure was performed in an elderly patient, who did not present any peri- or postoperative complications and obtained a satisfactory result, proving that it is an effective and safe technique to perform eye surgery. These procedures require dexterity and high sharpness of vision, which can be improved by robotics.[27] Roizenblatt et al.[23] claim that, in addition to canceling the tremor, the robot is able to scale the surgeon's movement, ensuring even more precision.

Gonzalez-Ciccarelli et al.[28] discussed the robotic approach to hepatobiliary surgery, whose advantage is its potential to overcome the technical limitations of laparoscopy. The robot enables the performance of complex hilum preparations and hepatocaval dissections as well as parenchymal transections with minimal blood loss. Robot-assisted liver resections enable the performance of complex reconstructions of vascular and biliary anastomoses, preserving the liver parenchyma in lesions located in the upper posterior segments, avoiding large hepatectomies. In experienced hands, larger and extensive hepatectomies can also be performed with excellent results. The limitations include large lesions, resections of posterosuperior segments, and results that are not generalizable in inexperienced hands. However, it is promising technology that could expand the indications for minimally-invasive hepatobiliary surgery.[28]

Gundlapalli et al.[29] reported a case of a patient who underwent right mastectomy, and the Da Vinci robot was used for breast reconstruction, more precisely for intra-abdominal dissection of the deep inferior epigastric vessels. This technique provided considerable precision to the surgical procedure, in addition to not leading to postoperative complications. However, further comparative studies are needed to assess the long-term outcomes and its cost-effectiveness.

Fiorelli et al.[30] compared the use of traditional endoscopic CO_2 laser in the treatment of subglottic stenosis with the AcuBlade laser system, performed through robotic microsurgery. The latter proved to be superior in reducing the chances of edema and the risk of recurrence, since it avoids injuring nearby tissues through laser dissipation, which is common in other techniques, and it can perform a more precise incision.[30]

Fu et al.[31] reviewed the role of transoral robotic surgery (TORS), transoral laser microsurgery (TLM), and lingual tonsillectomy in the identification of squamous cell carcinoma of the neck and head. The study[31] supported the use of TORS and TLM to assist in the identification of this tumor, with higher detection rates compared to the traditional diagnosis. The authors[31] also demonstrated that the addition of formal lingual tonsillectomy using TORS/TLM is a safe and effective option that can increase the yield of locating a primary occult tumor.[31] Kwong et al.[32] and Lörincz et al.[33] also wrote about the use of TORS in head and neck cancer, stating that it guarantees improved visualization, instrumentation, and ergonomics in transoral resections, with good results, in addition to playing the role of a multidisciplinary team in this field.

Additionally, Castellano and Sharma[34] performed a systematic review on the effects of TORS on the patient's quality of life after treatment and on the swallowing function of the patient with head and neck cancer. They[34] concluded that, when comparing patients who underwent TORS with those submitted to open surgery, the former had a higher score on the quality-of-life questionnaires and also showed an improvement in their swallowing function. However, the authors[34] note that the results depend on a few factors, such as baseline, T stage, and the status of the adjuvant treatment.[34] Another important point about TORS was highlighted by Chalmers et al.[35] in their study on the role of reconstruction in post-TORS defects, in addition to the role of robotic reconstruction in the medical practice.

Likewise, Li et al.[36] performed an analysis of the United States National Cancer database to compare the long-term outcomes of patients with oropharyngeal carcinoma treated with TORS, TLM, and non-robotic surgery. The study[36] evaluated the potential decrease in the risk of positive margins and the need for adjuvant chemoradiotherapy. However, the results showed that the survival rate was equivalent among all patients. Because of this, he authors[36] concluded that the TORS can be considered the primary surgical modality for the management of oropharyngeal carcinomas.

Moreover, Hanna et al.,[37] in their review, questioned whether robotic surgery is an option for early-T-stage laryngeal cancer, and compared TORS to TLM and partial open surgery in achieving negative margins, requiring adjuvant radiation. No difference was observed between the rates of positive margins of TORS and TLM, which suggests that TORS is a cancer-specific treatment option. Akst et al.[38] discussed robotic microlaryngeal phonosurgery, in which a new robotic ear, nose, and throat (ENT) microsurgery system (REMS) was developed, emphasizing cooperative control rather than remote control. This technology enables an improvement in surgical precision, and is subjectively easy to use, but future tests are still needed for its use in the clinical practice.

McGuire et al.[39] analyzed a series of cases, and concluded that there is potential for performing robotic microlaryngeal surgery (RMLS) using the Modular Oral Retractor (MOR) device, which reduces the need for lingual retraction suture, providing adequate exposure of the anterior commissure, enabling 360° access to the lesion, and eliminating the narrow view of the traditional laryngoscope. However, prospective research comparing RMLS and traditional microlaryngeal surgery is needed to determine the comparative results of each method.

Kim et al.[40] reported the cases of two patients diagnosed with tumors with mandibular invasion in which a 3D simulation software was used. Virtual surgical planning (VSP) is emerging as essential for mandibular reconstruction, due to the limited surgical field in the modified face-lift incision used in robotic neck dissection for oral cavity cancer. The authors[40] concluded that the VSP has an important role to play in the era of robotic surgery, even if still limited.

Saleh et al.[2] addressed the issue of plastic and reconstructive robotic microsurgery and concluded that robots will not replace surgeons; rather, they will only be sophisticated instruments used by surgeons. The major focus within robotic plastic surgery has been microvascular surgery; however, robotic surgery can be applied to all aspects of the reconstructive practice. Neurorobotic surgery, the harvest and insertion of flaps, dissection of donor and recipient vessels, and nerve or vascular graft harvesting can be performed with significantly reduced morbidity, improving patient outcomes. However, the current outcomes of robotic surgery are at least comparable to those of traditional methods with limited accessible evidence.

Dahroug et al.[41] reviewed microrobot-assisted otologic cholesteatoma surgery, and they concluded that there is still no robotic system capable of performing this surgery, but several interdisciplinary fields aim at the efficient implementation of this robotic system in the future. There are several obstacles, such as the engineering required to create a device so small, ergonomic and with the necessary accuracy. Ibrahim et al.[3] also suggested the possibility of the future implementation of robotics in this field.

Van Mulken et al.[42] performed a randomized pilot study comparing robotic and non-robotic supermicrosurgery of lymphatic venous anastomosis (LVA) in the treatment of breast-cancer-related lymphedema. Better results were observed in patients who underwent the robotic surgery, in addition to a reduction in the time to perform the anastomosis. Ibrahim et al.[3] have also mentioned robotic lymphedema surgery, noting that it is a microsurgical niche that requires a high degree of precision.

Ibrahim et al.[3] have also showed the clinical applications of robotic microsurgery. According to their study,[3] the robot helps provide precision and better visualization of the facial artery in microvascular surgery, and it is also able to perform peripheral nerve reconstruction in microneural surgery, due to its accuracy and steadiness.

Most studies[2,3,21–27,30,38] have stated that robotic microsurgery can decrease tremor and improve the surgeon's precision, resulting in a safe and promising technique. However, they have also agreed that it is a high-cost method, which is one of its few disadvantages. According to Fiorelli et al.,[30] the possibility of using robotics in other procedures, such as maxillofacial and otorhinologic surgeries, justifies the high cost. Furthermore, Edwards et al.,[26] Bourcier et al.,[27] and Kavoussi[24] have reported a longer operative time with the robotic technique when compared to conventional surgery, but the safety and efficacy of the method seemed to make up for this point. According to Bourcier et al.,[27] the longer time can be explained by the surgeons' inexperience with the robotic technique when compared to conventional surgery. On the other hand, Ibrahim et al.[3] have stated that another limitation of the technique is the small amount of tactile feedback when the surgeon uses a robot, concluding that training in the complex techniques of robotic microsurgery is essential for health professionals who are going to use it, as concluded Doulgeris et al.[43] on robotics in neurosurgery.

►**Table 1** summarizes the applications of robotic surgery studied.

Discussion

It is well known that the advent of robotic surgery and its unique features have provided microsurgeons with great levels of precision. In addition, with its high-definition, 3D optics and strong magnification, robotics offers a potentially ideal setup to perform the sensitive manipulations required in microsurgery. These minimally-invasive possibilities also enable microsurgeons to operate on in confined spaces, thus avoiding the need for open approaches, which in turn can improve the functional outcomes.[3]

Regarding robotic microvascular surgery, the robot's improved precision enables an easier performance of anastomoses in confined spaces, such as that of the facial artery, which reduces the number of additional incisions. In addition, robotic plastic and reconstructive microsurgery also seems to benefit from the new technology, with microvascular surgery being the major focus in this field.[2,3] Based on these advantages, robotic microsurgery also seems to gain momentum in hepatobiliary surgery, surpassing laparoscopic approaches.[28]

The unique features of robotic surgery are currently being expanded into the field of supermicrosurgery, specifically for lymphedema surgery. These are extremely challenging procedures from a technical point of view, and can exceed, in

Table 1 Applications of robotic surgery studied in the present systematic review

Article title	Author (year)	Study design	Application of robotic surgery
Intelligent Surgeon's Arm Supporting System iArmS in Microscopic Neurosurgery Utilizing Robotic Technology	Goto et al.[21] (2018)	Prospective observational study	Microneurosurgery
30 Years of Neurosurgical Robots: Review and Trends for Manipulators and Associated Navigational Systems	Smith et al.[22] (2016)	Literature review	Neurosurgery
Robotics in Neurosurgery: Evolution, Current Challenges, and Compromises	Doulgeris et al.[43] (2015)	Literature review	Neurosurgery
Validation of robot-assisted vasectomy reversal	Kavoussi[24] (2015)	Prospective interventional study	Vasectomy reversal
Robotic Surgery for Male Infertility	Darves-Bornoz et al.[25] (2021)	Literature review	Surgery for male infertility
First-in-human study of the safety and viability of intraocular robotic surgery	Edwards et al.[26] (2018)	Randomized clinical trial	Intraocular retinal membrane removal surgery
Robot-assisted tremor control for performance enhancement of retinal microsurgeons	Roizenblatt et al.[23] (2019)	Literature review	Eye surgery
Robotically Assisted Pterygium Surgery: First Human Case	Bourcier et al.[27] (2015)	Case report	Pterygium removal
Robotic approach to hepatobiliary surgery	Gonzalez-Ciccarelli et al.[28] (2017)	Systematic review	Hepatobiliary surgery
Endoscopic treatment of idiopathic subglottic stenosis with digital AcuBlade robotic microsurgery system	Fiorelli et al.[30] (2018)	Case report and review	Subglottic stenosis treatment
Improved Glottic Exposure for Robotic Microlaryngeal Surgery: A Case Series	McGuire et al.[39] (2017)	Case series	Robotic microlaryngeal surgery
Robotic microlaryngeal phonosurgery: Testing of a "steady-hand" microsurgery platform	Akst et al.[38] (2018)	Randomized clinical trial	Microlaryngeal phonosurgery
The role of transoral robotic surgery, transoral laser microsurgery, and lingual tonsillectomy in the identification of head and neck squamous cell carcinoma of unknown primary origin: a systematic review	Fu et al.[31] (2016)	Systematic review	Transoral robotic surgery
Is robotic surgery an option for early T-Stage laryngeal cancer? Early nationwide results	Hanna et al.[37] (2020)	Retrospective observational study	Early T-stage laryngeal cancer
Transoral robotic surgery in head neck cancer management	Kwong et al.[32] (2015)	Review	Transoral robotic surgery
Systematic Review of Validated Quality of Life and Swallow Outcomes after Transoral Robotic Surgery	Castellano and Sharma[34] (2019)	Systematic review	Transoral robotic surgery
Clinical Value of transoral robotic surgery: Nationwide results from the first 5 years of adoption	Li et al.[36] (2019)	Retrospective observational study	Transoral robotic surgery, transoral laser microsurgery and non-robotic surgery
First-in-human robotic supermicrosurgery using a dedicated microsurgical robot for treating breast cancer-related lymphedema: a randomized pilot trial	Van Mulken et al.[42] (2020)	Randomized pilot study	Robotic and non-robotic lymphatic venous anastomosis in lymphedema
Decision management in transoral robotic surgery: Indications, Individual patient selection, and role in the multidisciplinary	Lörincz et al.[33] (2016)	Literature review	Transoral robotic surgery

Table 1 (*Continued*)

Article title	Author (year)	Study design	Application of robotic surgery
treatment for head and neck cancer from a European perspective			
Robot-Assisted Reconstruction in Head and Neck Surgical Oncology: The Evolving Role of the Reconstructive Microsurgeon	Chalmers et al.[35] (2018)	Retrospective observational study	Transoral robotic surgery
The Role of Virtual Surgical Planning in the Era of Robotic Surgery	Kim et al.[40] (2016)	Case report	Mandibulectomy and mandibular reconstruction
Plastic and reconstructive robotic microsurgery—a review of current practices	Saleh et al.[2] (2015)	Systematic review	Plastic and reconstructive surgery
Review on Otological Robotic Systems: Toward Micro-Robot Assisted Cholesteatoma Surgery	Dahroug et al.[41] (2018)	Literature review	Cholesteatoma surgery
New Frontiers in Robotic-Assisted Microsurgical Reconstruction	Ibrahim et al.[3] (2017)	Literature review	Clinical applications: neurosurgery, ophthalmic, otologic, microvascular, microneural, and lymphedema surgeries, and vasectomy reversal
Robotic-assisted deep inferior epigastric artery perforator flap abdominal harvest for breast reconstruction: A case report	Gundlapalli et al.[29] (2018)	Case report	Da Vinci robot in mastectomy

certain cases, the limits of human precision, so the use of the robot in this scenario is beneficial. The studies included in the present systematic review corroborate this statement, with reports of the effectiveness of robotic surgery in the treatment of lymphedema.[3,42] Thus, with the use of robotic surgery, it is possible to better identify lymphatic insufficiency and pressure gradients, which are fundamental for lymphedema surgery, thus achieving promising results.[44]

In urology, robotic microsurgery has been used in vasoepididymostomy, subinguinal varicocelectomy, spermatic cord denervation, vasovasostomy, testicular artery reanastomosis, and vasectomy reversal. Studies[3,24,25] claim that robotics is a promising and effective technique in this filed, which yields results that are satisfactory and superior to those of conventional surgery.

In the field of microneurosurgery, the University of Calgary, Canada, has built the new and aforementioned NeuroArm, which provides visual, auditory and tactile feedback, creating an immersive environment for the neurosurgeon. NeuroArm was developed to perform standardized techniques (biopsy, microdissection, thermocoagulation, fine sutures), thus enabling the performance of procedures such as lesionectomy and aneurysm clipping,[45] with positive repercussions. In addition, studies[3,21,22,42] demonstrate that there is a possibility of using robotic microsurgery for the management of brain tumors, spinal cord injuries, as well as in brain stimulation.

Ophthalmologic and otologic robotic microsurgery have great potential as well. Recently, the Da Vinci Si HD robotic surgical system was tested and proved to be viable for ocular surface microsurgery. Retinal membrane removal surgery, as well as the treatment of pterygium, macular injury, diabetic retinopathy, and retinal vein canalization have also been shown to benefit from robotic surgery.[3,23,26,27] As for ear surgery, it has been noted that robotic microsurgery appears to be a promising method. However, technical developments are still needed to ensure the necessary accuracy in these procedures.[3]

There has been a great increase in the use of robots in transoral reconstructive microsurgery, reducing the morbidity associated with the excision of oropharyngeal tumors, which were previously accessible only by aggressive approaches. The current possibilities for TORS concern the reconstruction of postoperative defects, oropharyngeal carcinomas, laryngeal cancer, in addition to the treatment of other types of head and neck cancer and glottic stenosis. Therefore, there is a wide range of applications of TORS, as well as of its benefits in relation to manual surgery. According to several authors,[30–32,34,36–39] robotics ensures better accuracy, precision and ergonomics in this field, enabling the performance of innovative techniques.

Elimination of the hand tremors seems to be one of the main advantages of robotic surgery over conventional techniques, and this is the biggest challenge for surgeons in microsurgery. In addition, it has been recognized that the technique ensures greater sharpness of vision and surgical precision, resulting in safer and often more effective surgeries compared to manual surgery. Among the disadvantages of robotics, the studies[2,3,21–27,30,35,38,43] mainly emphasize the high cost and longer surgical time in many procedures. This last disadvantage seems to be a consequence of the surgeons' lack of experience with the new technology, which can be overcome in the future with adequate training and practice on the part of the professionals.

Conclusion

From the present systematic review, we conclude that there is great room for robotics in microsurgery. The selected studies point to a great perspective for the growth of these practices, which are based on the use of robotics in the most varied fields, such as microneurosurgery, biopsy and microdissection, primary procedures for male infertility, and eye and ear surgeries. Another branch with exponential growth is in transoral surgery, which is a safe and effective option for the identification and treatment of various head and neck tumors. In addition, other approaches such as hepatobiliary surgery and surgery for the treatment of lymphedema can be performed using robots, and this new technology is therefore promising. The guarantee of dexterity, sharpness of vision, and surgical precision translate into a safe and auspicious technique, applicable in different fields of microsurgery.

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