OPEN

PRS GLOBAL OPEN

IDEAS AND INNOVATIONS

Peripheral Nerve

Nerve Transfers Using a Dedicated Microsurgical Robotic System

Benedikt Schäfer, MD*†
Jörg Bahm, PhD, MD*†
Justus P. Beier, MD*

Summary: Microsurgical demands in peripheral nerve surgery are increasing. Because of the development of multiple simultaneous selective nerve transfers, the transposition of very small nerves and even single fascicles has evolved. Coaptation of these increasingly smaller structures require high skills in microsurgical techniques. In addition, the surgical situs often has very limited access and is difficult to reach with conventional microsurgical options. Robot technology, the Symani Surgical System (Medical Microinstruments, S.p.A, Calci, Pisa, Italy), was used for epineural coaptation of three donor nerves (intercostal nerves 4–6) to the long thoracic nerve and the thoracodorsal nerve as recipient nerves in a patient with brachial plexus palsy. The coaptations could be carried out successfully with the microsurgical robot technology. In combination with a high-magnification (up to 26×) 3D-exoscope, the epineural sutures could be placed very precisely and accurately. Using this new microsurgical robotic system, successful coaptation of very small nerve structures is possible. This opens possibilities for the microsurgeon to carry out even finer, more targeted and more complex nerve transfers, including procedures in anatomical regions that are difficult to reach. *(Plast Reconstr Surg Glob Open 2023; 11:e5192; doi: 10.1097/GOX.0000000000005192; Published online 14 August 2023.)*

INTRODUCTION

After the first description of nerve transfers,[1] further developments enabled increasingly selective nerve transfers and reconstruction of very small structures.[2,3] Finally, humane capabilities are posing the limits for further miniaturization, for example, by the physiological tremor. To overcome these limitations, development of a dedicated microsurgical robotic platform opens new horizons in microsurgery. Recently, lymphovenous anastomoses[4] and a vascular anastomosis for free flap transplantation have been performed for the first time.[5] Until now, there is no description of the use of a dedicated microsurgical robotic technique in peripheral nerve surgery. Here, we present our experience with the use of a dedicated microsurgical robotic platform in peripheral nerve transfer.

*From the *Department of Plastic Surgery, Hand Surgery – Burn Center, University Hospital RWTH Aachen, Aachen, Germany; and †Division for Plexus Surgery, University Hospital RWTH Aachen, Aachen, Germany.*

Received for publication May 17, 2023; accepted June 29, 2023.

DOI: 10.1097/GOX.0000000000005192

METHODS

Robot Technology and Training of Microsurgeons

The CE-certified robotic microsurgical system (Symani Surgical System, Medical Microinstruments, S.p.A, Calci, Pisa, Italy) provides microsurgical work very precisely in a less than 1 mm range, using principles of teleoperation with motion scaling (7–20×) and complete elimination of human tremor. The 4K-3D exoscope provided 26× magnification (13× optical magnification/twofold digital), while leaving enough open space above the operation field for robotic arms and instruments during nerve coaptation. Robotic instruments offer seven degrees of freedom in motion, making movements that are impossible for a human's hand. The microsurgeon performs surgery from the console of the system, from where an optimal image of the situs is provided by the 4K 3D exoscope (ORBEYE 4K 3D Orbital Camera System, Olympus Europa SE & Co. KG, Hamburg, Germany). In preparation for this operation, intensive training was performed, including nerve coaptation in the chicken leg model so that the system can be used safely and in an efficient manner.

Case Presentation

A 16-year-old patient presented to our clinic 3 months after polytrauma. Complete palsy of the right arm was initially diagnosed. Magnetic resonance imaging suggested

Disclosure statements are at the end of this article, following the correspondence information.

avulsion of the lower roots of the right plexus. During brachial plexus exploration, we confirmed root avulsion of C7 to Th1 with neuropathological assessment showing fibrotic C6 root. Only C5 root could be used and was connected to the superior trunk via sural nerve grafts and split accessory nerve (N XI) coaptation to suprascapular nerve. In a second operation, contralateral C7 transfer was performed with a vascularized ulnar nerve transplantation. In a third operation, selective nerve transfer from intercostal nerves to long thoracic nerve and thoracodorsal nerve with coaptation of fifth intercostal nerve to the long thoracic nerve and fourth and sixth intercostal nerve to the thoracodorsal nerve using the Symani Robotic System for preparing their muscles as possible donors for future muscle transfers was done. Further intra- and postoperative course was uneventful (Figs. 1–3).

DISCUSSION

In this case, we performed the first nerve coaptation using a dedicated microsurgical robot. Safety and reliability of the system was demonstrated. Thus, the microsurgical toolbox of peripheral nerve surgeons could be expanded by this promising new and innovative platform. The system has so far been used in supermicrosurgery of lymphatic vessels[4,6] and a first patient with vascular flap anastomosis.[5] In other specialties, the DaVinci robotic surgical system (Intuitive Surgical Operations, Inc., Sunnyvale, Calif.) has been an integral surgical tool for several years.[7] Efforts have already been made to use the DaVinci system in microvascular surgery[8] and peripheral nerve surgery, the latter by using it for minimally invasive exploration and reconstruction of the brachial plexus[9,10] and nerve transfers.[11,12] However, significant limitations were observed, including poor visualization with lower magnification than conventional microscopes and nonmicrosurgical robotic instruments. In an extensive review by Chen et al,[13] robotic assisted microsurgery was analyzed, evaluating 19 studies, including brachial plexus reconstruction, different other peripheral nerve operations, animal studies, and cadaveric studies. Of the 53 clinical cases, only 20 (37.7%) cases were successfully approached with a minimally invasive method and intervened robotically. Seventeen (32.1%) cases underwent a conventional approach, and the nerves were intervened robotically as in our case. The Symani Surgery System is only approved for surgery with open approach. Twelve (22.6%) cases were converted to open approach, but the nerve was still intervened robotically, and four (7.5%) cases were completely converted to open surgery.[13] It is important to emphasize that all other robot systems, in contrast to the Symani Surgery System, were not developed specifically for microsurgery. So far, no dedicated microsurgical robot technology has yet been established that has fully reached everyday clinical practice. Performing surgery

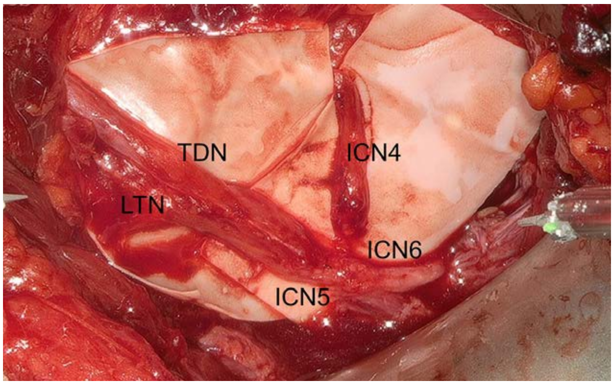

Fig. 1. Demonstration of the nerves before coaptation. LTN, long thoracic nerve; TDN, thoracodorsal nerve; ICN 4–6, intercostal nerves 4–6.

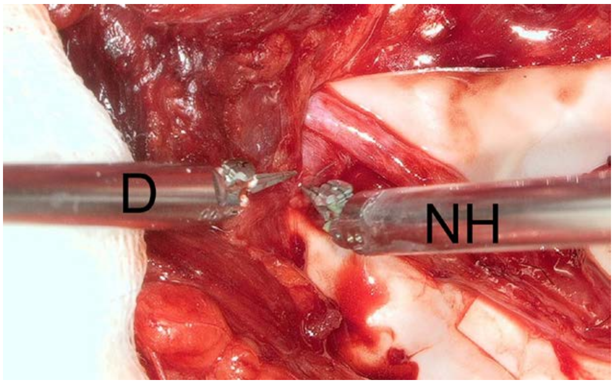

Fig. 2. Robot-assisted coaptation of the intercostal nerve 5 to long thoracic nerve, using microinstruments. NH, needle holder with integrated scissors; D, dilatator.

Takeaways

Question: Is a microsurgical robotic system suitable for nerve transfer surgery?

Findings: First-time triple nerve transfer was performed with a dedicated microsurgical robotic system.

Meaning: A microsurcgical robotic system holds promise for nerve transfer surgery.

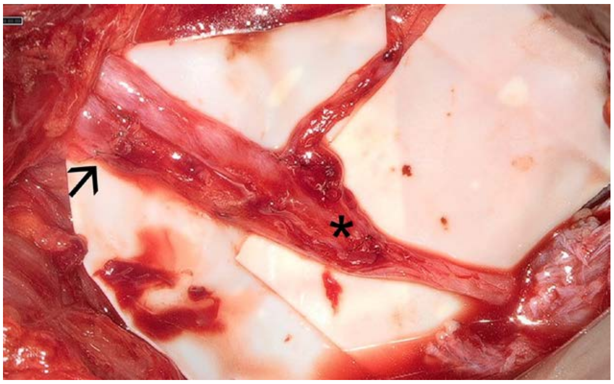
Fig. 3. Successful coaptation of ICN 5 to LTN (→) and ICN 4 + 6 to TDN (*).

with robotic technology enables microsurgical reconstruction in a hard-to-reach situs under optimized ergonomic conditions.[14] The Symani Surgery System, together with an ultra-high definition (4K = 3840×2160 pixel) exoscopic 3D visualization with up to 26-fold magnification of the surgical site, offers a possibility for accurate reconstruction of the smallest structures. Microsurgical sutures can be carried out precisely based on motion-scaling at a factor of 7–20× and the complete reduction of the human physiological tremor. Potential drawbacks, like the initial learning curve, future cost/reimbursement issues, and the most critical question of scientifically proven evidence for the superiority of a robotic versus conventional nerve coaptation technique will be subject to ongoing and future investigations. Like in many other current technologies and methods in modern plastic surgery,[15–17] the first ever application of a novel technology comes with limitations and challenges to be addressed and possibly overcome in the future of more routinely applying those technologies. Of course, this includes the more time-consuming coaptation at the very beginning of our learning curve. However, this is likely to improve over time of practicing this new innovative technology.

CONCLUSIONS

We demonstrated the successful use of the dedicated microsurgical robot system in peripheral nerve surgery. So far, the system has been used in lymphatic surgery for anastomosing lymphovenous anastomosis as well as an artery and vein in a free flap procedure. In our opinion, the Symani Surgery System can enable highly precise coaptations of the smallest nerve structures in areas that are difficult to reach. As a result, the spectrum of peripheral nerve transfers could possibly further be expanded even more in the future.

Justus P. Beier, MD
Department of Plastic Surgery, Hand Surgery – Burn Center
University Hospital RWTH Aachen
Pauwelsstr. 30, 52074 Aachen
Germany

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

REFERENCES

1. Vulpius O, Stoffel A. *Orthopädische Operationslehre*. Stuttgart, Germany: Enke; 1910;*1*.
2. Mavrogenis AF, Markatos K, Saranteas T, et al. The history of microsurgery. *Eur J Orthop Surg Traumatol*. 2019;29:247–254.
3. Tamai S. History of microsurgery. *Plast Reconstr Surg*. 2009;124:e282–e294.
4. Lindenblatt N, Grunherz L, Wang A, et al. Early experience using a new robotic microsurgical system for lymphatic surgery. *Plast Reconstr Surg Glob Open*. 2022;10:e4013.
5. Innocenti M, Malzone G, Menichini G. First-in-human free-flap tissue reconstruction using a dedicated microsurgical robotic platform. *Plast Reconstr Surg*. 2023;151:1078–1082.
6. Grunherz L, Gousopoulos E, Barbon C, et al. [Robotics in plastic surgery]. *Chirurgie (Heidelb)*. 2023;94:325–329.
7. Leal Ghezzi T, Campos Corleta O. 30 years of robotic surgery. *World J Surg*. 2016;40:2550–2557.
8. Selber JC. Transoral robotic reconstruction of oropharyngeal defects: a case series. *Plast Reconstr Surg*. 2010;126:1978–1987.
9. Garcia JC, Jr, Lebailly F, Mantovani G, et al. Telerobotic manipulation of the brachial plexus. *J Reconstr Microsurg*. 2012;28:491–494.
10. Mantovani G, Liverneaux P, Garcia JC, Jr, et al. Endoscopic exploration and repair of brachial plexus with telerobotic manipulation: a cadaver trial. *J Neurosurg*. 2011;115:659–664.
11. Naito K, Facca S, Lequint T, et al. The Oberlin procedure for restoration of elbow flexion with the da Vinci robot: four cases. *Plast Reconstr Surg*. 2012;129:707–711.
12. Miyamoto H, Leechavengvongs S, Atik T, et al. Nerve transfer to the deltoid muscle using the nerve to the long head of the triceps with the da Vinci robot: six cases. *J Reconstr Microsurg*. 2014;30:375–380.
13. Chen LW, Goh M, Goh R, et al. Robotic-assisted peripheral nerve surgery: a systematic review. *J Reconstr Microsurg*. 2021;37:503–513.
14. Howarth AL, Hallbeck S, Mahabir RC, et al. Work-related musculoskeletal discomfort and injury in microsurgeons. *J Reconstr Microsurg*. 2019;35:322–328.
15. Boissiere F, Gandolfi S, Riot S, et al. Flap venous congestion and salvage techniques: a systematic literature review. *Plast Reconstr Surg Glob Open*. 2021;9:e3327.
16. Guarro G, Cozzani F, Rossini M, et al. The modified TIME-H scoring system, a versatile tool in wound management practice: a preliminary report. *Acta Biomed*. 2021;92:e2021226.
17. Winter E, Glauser G, Caplan IF, et al. The LACE+ Index as a predictor of 30-day patient outcomes in a plastic surgery population: a coarsened exact match study. *Plast Reconstr Surg*. 2020;146:296e–305e.