CLINICAL TECHNIQUES AND TECHNOLOGY

The natural evolution of endoscopic approaches in skull base surgery: robotic-assisted surgery?

La naturale evoluzione degli approcci endoscopici alla base cranica: la chirurgia robotica-assistita?

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SUMMARY

The current surgical trend is to expand the variety of minimally invasive approaches and, in particular, the possible applications of robotic systems in head and neck surgery. This is particularly intriguing in skull base regions. In this paper, we review the current literature and propose personal considerations on the role of robotic techniques in this field. A brief description of our personal preclinical experience on skull base robotic dissection represents the basis for further considerations. We are convinced that the advantages of robotic surgery applied to the posterior cranial fossa are similar to those already clinically experienced in other areas (oropharynx, tongue base), in terms of tremor-free, bimanual, precise dissection: the implementation of instruments for bony work and resolving current drawbacks will definitely increase the applicability of such a system in forthcoming years.

KEY WORDS: DaVinci robotic system • Skull base • Endoscopic • TORS • Robotic surgery

RIASSUNTO

Il trend attuale, in ogni ambito chirurgico, è quello che porta verso una sempre minore invasività delle procedure; nel distretto testa-collo una delle più recenti tendenze è quella di verificare l'applicabilità clinica delle nuove tecnologie robotiche. Questa evoluzione si presenta particolarmente interessante ed intrigante soprattutto in ambito di chirurgia della base cranica. In questo lavoro presentiamo una revisione delle recente letteratura sull'argomento e proponiamo le nostre personali considerazioni sul ruolo delle tecniche robotiche nel campo della chirurgia di base cranica. Una breve descrizione della nostra esperienza dissettoria eseguita utilizzando il DaVinci a livello di base cranica posteriore rappresenta lo spunto per ulteriori considerazioni. Siamo del tutto convinti che gli stessi vantaggi offerti dalla chirurgia robotica a livello orofaringeo – dissezione bimanuale, precisa e priva di tremore – si applicheranno anche a livello della base cranica posteriore e media. In tale contesto lo sviluppo e l'implementazione di strumenti per la gestione dell'osso e la risoluzione dei limiti attuali incrementerà l'applicabilità clinica di questi sistemi nel prossimo futuro.

PAROLE CHIAVE: *Sistema robotico DaVinci • Chirurgia di base cranica • Chirurgia robotica • Chirurgia robotica transorale • Endoscopia*

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Introduction

Skull base surgery is technically demanding. Since its first curative attempts dating back to the last part of the 19th century [1 2], things have changed dramatically [3]. Pioneering experiences required extensive disassembling of the bony structures of the face and the head in order to reach the target areas. The introduction of microscopic techniques increased the ability to dissect in complex regions, and offered the surgeon two-hand work and a 3D environment. Notwithstanding, major work on the bony skeleton is still required. Introduction of endoscopy through natural orifices, and more recently also through surgical corridors, has revolutionized the way skull base lesions can be accessed and managed. What has really been improved with the introduction of the endoscope is the vision of the target and surrounding regions. The conal vision offered by every external approach, including a microscopic one, has been substituted by a panoramic and dynamic vision offered by the endoscope. The ability to look around the corner and to go close to the target areas are probably the most important advantages offered by endoscopic techniques. Given the fact that surgery is a matter of obtaining a visible surgical field, it is easy to understand the value of this philosophical, rather than technical, innovation. In other words, the endoscope has completely modified

the point of view of surgical procedures. Over the last 10 years, as testimony to this "conceptual revolution", an enormous number of papers on an endoscopic, transnasal and non, approach to the skull base has been reported [4-8]. Many centres worldwide have gained remarkable experience in this field and new limits are being reached and surpassed day by day, while new corridors are proposed and investigated continuously. What is true at the time of writing can be surpassed at the time of reading. If not yet, it will certainly be so with time.

Obviously every coin has two faces, and traditional endoscopic techniques are associated with flaws and limitations. Typically, detractors of this technique underline 2 main concerns. The first one is the lack of 3D vision, and the second is the difficulty of bimanual work. If the first concern was true until some years ago, with the introduction of the 3D endoscope, endosurgeons now have the possibility to work in a true 3D environment. In this respect, previous experiences, including ours [9-12], demonstrate significant advantages with the use of 3D techniques. If some limitations still remain, they will undoubtedly be resolved with time. With regard to the second concern, the introduction of a typical neurosurgical bimanual dissection technique, especially due to the work of the Pittsburgh group, has completely resolved the problem. In this respect, we perfectly agree with Kupferman who states that the ideal surgical technique should offer the surgeon the distinct advantage of 3D vision and bimanual surgical dissection [13], possibly guided by a navigation system. Based on this, we maintain that a standard setting for endoscopic skull base surgery should offer all these opportunities to the surgeon and patient. Grounded on these considerations, we present herein the current state of art regarding the potential application of a robotic technique at the level of the skull base, trying to answer questions about the future role of such technology in this exciting area. Our preclinical experience on this topic – briefly described below – represents the basis for a critical evaluation of the data presented in the current literature.

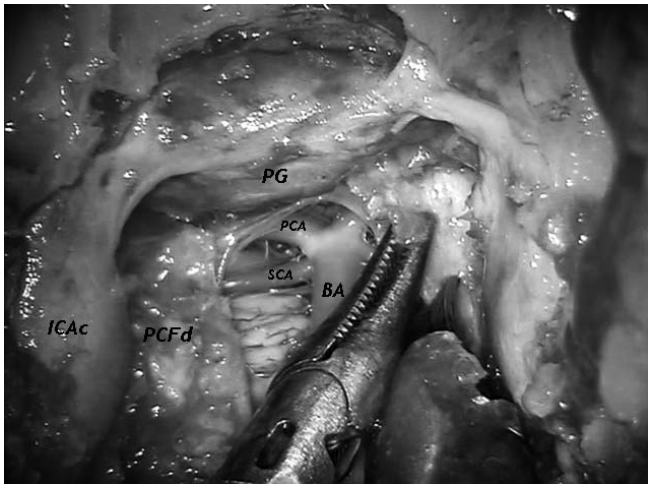

Fig. 1. Endoscopic view of the initial phase of robotic dissection-namely the opening of the posterior cranial fossa dura. The 0° scope is placed transnasally. BA-basilar artery, PG-pituitary gland, PCA-posterior cerebral artery, SCA-superior cerebellar artery, ICAc-cavernous portion of the internal carotid artery, PCFd-dura of the posterior cranial fossa.

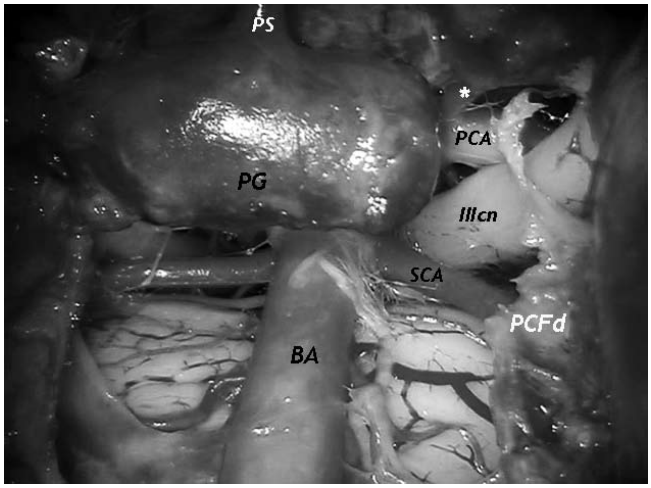

Fig. 2. Close vision of the pituitary and upper basilar tip region. Vision obtained with a 0° scope, placed transnasally. PG-pituitary gland, PS-pituitary stalk, BA-basilar artery, SCA-superior cerebellar artery, PCA-posterior cerebral artery, white asterisk-posterior communicating artery, IIIcn-oculomotor nerve, PCFd-dura of the posterior cranial fossa.

Technique

The DaVinci system is placed cranially at the head of the cadaver. As previously described [14], the endoscope and the trocars are placed transnasally and paramandibularly, respectively. With this setting an extraordinary and familiar view of the middle and posterior ventral skull base is gained. Bony work – creation of an operative sphenoclival window – is done by traditional endoscopic techniques, given the actual absence of dedicated "robotic" instruments for bone. At this point, the dura of the middle and posterior cranial fossa is exposed and, once opened, a delicate dissection of these areas is performed. Pituitary and basilar tip regions are easily dissected and a pituitary transposition is performed, thus exposing and identifying the noble structures. Oculomotor nerves, superior cerebellar and posterior cerebral arteries, posterior communicating arteries (Figs. 1, 2), abducens nerves and the pituitary vascularization can be visualized through the sphenoclival window. As a whole, during dissection, conflict between instruments is minimal and can be reduced with good placement of trocars.

Discussion

Current endoscopic transnasal techniques, regardless of the use of 2- or 3D endoscopes, represent a valid alternative to traditional external approaches and are probably the gold standard in selected cases of skull base patholo-

gies, especially when dealing with ventral skull base lesions [5 15-19]. However, limits and disadvantages still exist. Thus, following the evolving course of minimal invasiveness, since the pioneering work of the Philadelphia group [20-22], an increasing interest in robotic technologies is growing. In clinical settings, robotic procedures in the head and neck area are performed, placing the scope and the arms transorally. At present, these procedures are now being applied outside the region of the first experiences, namely the oropharynx [23-25]. Nonetheless, up to now no clinical series regarding ventral skull base lesion management have been reported, with the unique exception of a blended solution on cranio-cervical junction [26]. As a corollary, a small series on parapharyngeal lesion management has been recently reported by the "Penn" group [27]. On the other hand, there is significantly more consistent preclinical literature on this topic [13 28-33], thus witnessing a growing "robotic" interest in skull base regions. Historically, the first attempts to approach skull base using of a robotic system were pioneered by the "Penn" and the "MD Anderson" groups [28 29]. However, one obvious question is whether the robotic technique is the natural evolution of "traditional" endoscopic techniques for skull base regions? Certainly current robotic systems undoubtedly offer the surgeon an excellent view of the surgical field and an incredibly precise and intuitive manoeuvrability of the arms. The strengths of the robotic system are well-known and their description is outside the scope of this paper. Notwithstanding, the daVinci system presents several limits, especially when dealing with the skull base regions. This is simply related to the fact that the system has been conceived and built to work in large spaces and not in small corridors. In this respect, when dealing with narrow areas, such as the skull base, the arms of the system should work parallel to one another to avoid conflict. Yet with current instrumentation this is not possible and a small amount of conflict is present, especially in the traditional transoral setting. For this reason, and to overcome these limits, different solutions and settings have been proposed in preliminary cadaveric experiences [14 28 29]. Among the solutions suggested, we maintain that the combination of the transnasal placement of the scope and the transcervical placement of the trocars offers the best option, at the lowest biological price, with current instrumentation. By placing the endoscope transnasally, we obtain a more familiar, panoramic and orientating view of the surgical field, while, with the traditional transoral placement of the scope – 30° upfaced – we obtain a down-to-up vision, truly unfamiliar and not particularly orientating. This viewpoint makes working less comfortable and less safe in the upper regions. Compared to trocars, if they are placed paramandibularly, it is possible to gain a greater manoeuvrability of instruments in the upper regions. In contrast, transoral placement of the trocars needs complete palatal splitting, if superior work is to be done. Previous experience including our own shows similar conclusions in this respect [14 29]. We are aware that our setting [14], like the previous ones [28 29], takes advantage of another portal for robotic arms to achieve an improved position of the arms, and that all these solutions sacrifice the minimally invasive nature of the procedure. However, it is not particularly different from that observed in robotic transabdominal and transthoracic procedures where different portals are used to gain greater manoeuvrability and efficacy. With this setting, once the bony structures have been removed, a delicate dissection of the dural layers of the middle and posterior ventral skull base and intracranial structures is possible, thus demonstrating a technical feasibility in preclinical models. A precise and tremor-free dissection of the pituitary region and the prepontine cistern is performed. Obviously, the system presents significant limitations that preclude current application in clinical settings for skull base pathologies.

Among the drawbacks of this new technology we must point out the absence of tactile feedback. This is an important limitation of the daVinci system that must be addressed in the future. Certainly with the implementation of instruments for bony work, currently lacking but which will soon be available, the applicability of such systems will be increased in the forthcoming years. As a consequence, a fully robotic skull base surgery will require the development of new tools for the daVinci robotic arms. In this respect, we strongly call for close collaboration with the manufacturer. From an anatomical viewpoint, with the current setting and instrumentation, the intercarotic space at the level of the clivus represents a critical factor that impacts the ability to dissect the posterior cranial fossa and pituitary regions. A wide bony corridor is necessary and the more space is available, the easier and more delicate the dissection is. However, it must be stressed that this kind of problem is also present with traditional endoscopic transnasal procedures.

Lastly, but of minor significance, with current instrumentation a conflict between the scope and the piriform aperture may be present during the nasal time. In fact, the current scope completely fills the piriform aperture. In spite of this, we maintain that it is a false problem for mainly two reasons. Firstly, with technical evolutions smaller lenses will become available, and secondly the piriform aperture can be widened as necessary without any discomfort for the patient.

Finally, some general considerations on the economic aspects are warranted. Costs remain an impediment to the establishment of robotic programs, as evaluated by others [34]. These costs include purchase, annual maintenance and cost per case. Obviously centres with high volume robotic procedures for other varying specialities are more likely to expand into otolaryngology. In this respect, by expanding patient access to minimally invasive techniques, increasing the number of treated cases and im-

proving outcomes, all parties involved (patients, surgeons and the healthcare system in general) will benefit from a robotic programme. In this scenario, given the expected clinical benefits, the significant initial costs are justified. Personally, we are strongly convinced that robotic applications in skull base regions will not be an exception to this rule.

In conclusion, based on our clinical experience in both endoscopic transnasal skull base and transoral robotic procedures, we believe that the ability to perform precise, tremor-free, bimanual surgery in confined cavities with instrumentation that exceeds the capabilities of the human hand [13] truly represents a great opportunity for surgeons and patients. In this respect, we are strongly convinced that robotic systems can be considered the natural evolution of traditional endoscopic techniques and that the future will offer the concept of surgical modularity: the combination of different corridors and techniques will create a blended solution in which the target of the therapy is addressed in the best possible manner, and no longer according only to the surgeon's advantage, but rather to the patient's. Clearly, the road to the future must be taken by all of us together in a synergic and multidisciplinary manner, and what has been true in the past is still true today. We must continue to improve our understanding of anatomy, whether endoscopic or traditional, to develop new surgical instruments, describe new surgical approaches and validate new technological solutions. To think that the utmost has been discovered would be a great mistake. Techniques, technologies and instrumentations will change, as will ideas and approaches, but what must not change is the reason for our mission: the patient. Time will certainly judge our personal viewpoint.

Conclusions

Skull base regions, for years considered inaccessible, are now manageable with increasing safety and efficacy. The evolution of this surgery has given birth to a new professional figure: the skull base surgeon. In this particular field, robotic technology represents an exceptional opportunity for both the patient and surgeon. The combination of frameless neuronavigation, modular approaches, intraoperative imaging systems, new materials and robotic surgery will offer incredible opportunities. What is certain is that they will be surpassed by further evolution. In any case, we are strongly convinced that skull base pathologies need a well-coordinated skull base team, and not just a single *deus ex machina,* that is skilled in using all the technical innovations available for the best interests of the patient.

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