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REVIEW

Transclival approaches for intradural pathologies: historical overview and present scenario

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Abstract

Recently, endoscopic transsphenoidal transclival approaches have been developed and their role is widely accepted for extradural pathologies. Their application to intradural pathologies is still debated, but is undoubtedly increasing. In the past five decades, different authors have reported various extracranial, anterior transclival approaches for intradural pathologies. The aim of this review is to provide a historical overview of transclival approaches applied to intradural pathologies. PubMed was searched in October 2018 using the terms transcliv*, cliv* intradural, transsphenoidal transcliv*, transoral transcliv*, transcervical transcliv*, transsphenoidal brainstem, and transoral brainstem. Exclusion criteria included not reporting reconstruction technique, anatomical studies, reviews without new data, and transcranial approaches. Ninety-one studies were included in the systematic review. Since 1966, transcervical, transoral, transsphenoidal microsurgical, and, recently, endoscopic routes have been used as a corridor for transclival approaches to treat intradural pathologies. Each approach presents a curve that follows Scott's parabola, with evident phases of enthusiasm that quickly faded, possibly due to high post-operative CSF leak rates and other complications. It is evident that the introduction of the endoscope has led to a significant increase in reports of transclival approaches for intradural pathologies. Various reconstruction techniques and materials have been used, although rates of CSF leak remain relatively high. Transclival approaches for intradural pathologies have a long history. We are now in a new era of interest, but achieving effective dural and skull base reconstruction must still be definitively addressed, possibly with the use of newly available technologies.

Keywords Transclival approaches · History · Clivus · Reconstruction materials · Reconstruction techniques · CSF leak

Abbreviations

3D	Three-dimensional
CSF	Cerebrospinal fluid

Introduction

The past two decades have witnessed the rise and development of endoscopic transnasal skull base surgery [1, 2]. Among the different endoscopic transnasal approaches developed, the transclival has been widely accepted for extradural pathologies, mainly clival chordomas, but its use remains highly debated for intradural lesions due to the high rate of post-operative CSF leak [3]. The advantages that make the endoscopic transclival approach a promising technique to treat midline posterior fossa pathologies consist in avoiding cerebral retraction, near-field magnification, better surgical field illumination, minimal manipulation of neurovascular structures, and direct access to the tumor as well as early access to its vascular supply and the possibility of removing the involved bone and/or dura [3].

In the past five decades, different anterior extracranial and transclival approaches have been described for intradural pathologies, together with variable reconstructive techniques. This is most probably due to the high potential of anterior transclival approaches as they provide a direct, unhindered view of the anterior surface of the brainstem, together with its cisterns and contents, compared to lateral transcranial approaches [4–7].

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The aim of this paper is to provide a systematic historical overview of anterior, extracranial transclival approaches for intradural pathologies, together with an account of the current reality of endoscopic transclival surgery for intradural lesions.

Materials and methods

PubMed was searched in October 2018 using the terms transcliv*, cliv* intradural, transsphenoidal transcliv*, transoral transcliv*, transcervical transcliv*, transsphenoidal brainstem, and transoral brainstem.

Exclusion criteria included not reporting reconstruction technique, anatomical studies, reviews on the topic with no new data, and transcranial approaches.

The studies included were analyzed for different features, including pathology, type of approach, reconstruction technique and material used for reconstruction, number of reports, and reporting centers.

Results

The review process, according to PRISMA guidelines, is reported in Fig. 1. Ninety-one studies were included in the systematic review (Fig. 1).

The results of the data analysis are reported according to the different features analyzed: type of approach (Fig. 2), number of centers publishing data on the topic (Fig. 3), pathologies treated (Fig. 4), and reconstruction materials (Fig. 5).

Discussion

The history of transclival approaches is characterized by "waves" of procedures and techniques reported following the principle of Scott's parabola [8, 9]. The parabola describes the rise and fall of new surgical techniques. These are initially described with enthusiasm, may become widely used, and then fall into disuse after reports of complications [8, 9].

Surgical approaches

The first parabola may be constituted by the transcervical approach, which was the only approach reported in the 1960s [10–12]. It was not reported in later studies, except for the works by Koechlin et al., which described a combined endonasal and transcervical approach in 2014 [13], and by Hanakita et al., that performed an endonasal approach combined to the far lateral approach in 2018 [14].

The transoral approach seems to correspond to a second parabola. From the 1970s to 2001, most authors reported a transoral approach [1, 15–32]. Nevertheless, a few cases using transfacial approaches [33] and one case of endonasal approach [34] were reported in the same years (Fig. 2).

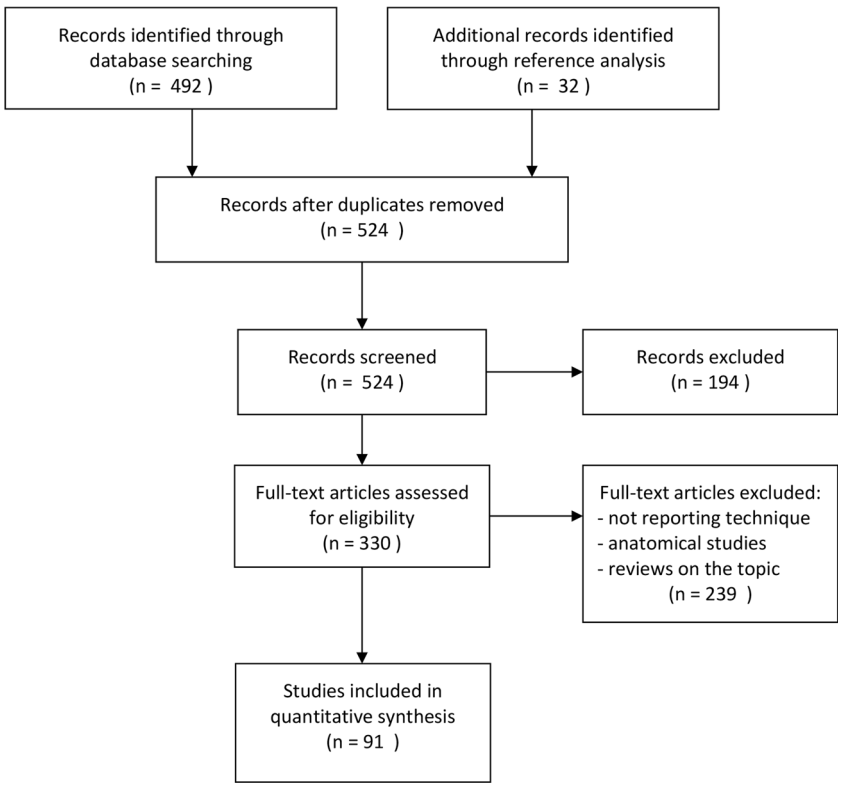

Fig. 1 Review process according to PRISMA guidelines (see text for further details)

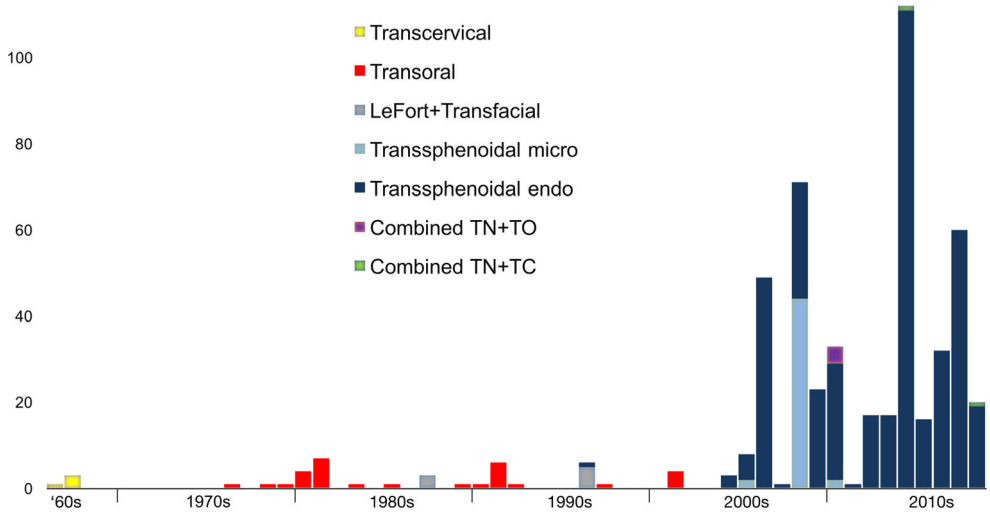

Fig. 2 Diffusion of different transclival approaches during time. Graphic rendering of number of cases, from 1967 to 2018, treated with different anterior, extracranial approaches to the clivus, with different colors according to the used approach. Micro, microsurgical; endo, endoscopic; TN, transnasal; TO, transoral; TC, transcervical

From 2004 to 2018, most authors used a transnasal approach [2, 35–52]. Microsurgical approaches were reported up to 2010 [35, 39, 40, 53], including combined transoral and transnasal approaches [51]. In the following years, only endoscopic endonasal transclival approaches have been reported [3, 35, 36, 43, 44, 52, 54–94] (Fig. 2).

It is also evident that reports on the topic have been published discontinuously until the beginning of this century (Figs. 2 and 3). On the contrary, papers on endoscopic transclival approaches have been published every year since 2004 (Figs. 2 and 3). Furthermore, at least two papers, based on data from different centers, have been published every year since 2008 (Fig. 3). Globally, an increasing trend in the number of centers performing transclival approach is suggested by the increasing number of centers publishing on the topic.

Pathology

The results regarding treated pathologies also show a growing trend in the number of cases treated with a transclival approach (Fig. 4). The most significant increase was seen in 2006, mostly due to the reports of surgical operations for intradural pathologies, extradural clival pathologies with intradural extension, or surgery with evidence of intraoperative dural defects (Fig. 4) [2, 3, 35–37, 39, 46, 49, 52, 54–58, 60–64, 66, 68–84, 89–91, 94, 95]. Furthermore, the results showed an initial preponderance of vascular pathologies treated via a transclival approach (Fig. 4), mainly posterior circulation aneurysms and some cavernous malformations of the brainstem. Intradural pathologies, including meningiomas, schwannomas, epidermoid cysts, and neuroenteric cysts, were reported sporadically in the 1990s, and showed a significant increase since 2005, parallel with the evolution of transnasal endoscopy [2, 3, 35–37, 39, 46, 49, 52, 54–58, 60–64, 66, 68–84, 89–91, 94, 95]. The main boost to the widespread use of endoscopic transclival approaches was most probably the huge impact that the introduction of this technique had on outcomes of patients treated for clival chordomas. It has been recently shown that the endoscopic approach leads to a high rate of tumor removal and symptom control, with low morbidity and preservation of a good quality of life [96]. A decrease in vascular indications has been observed over the last

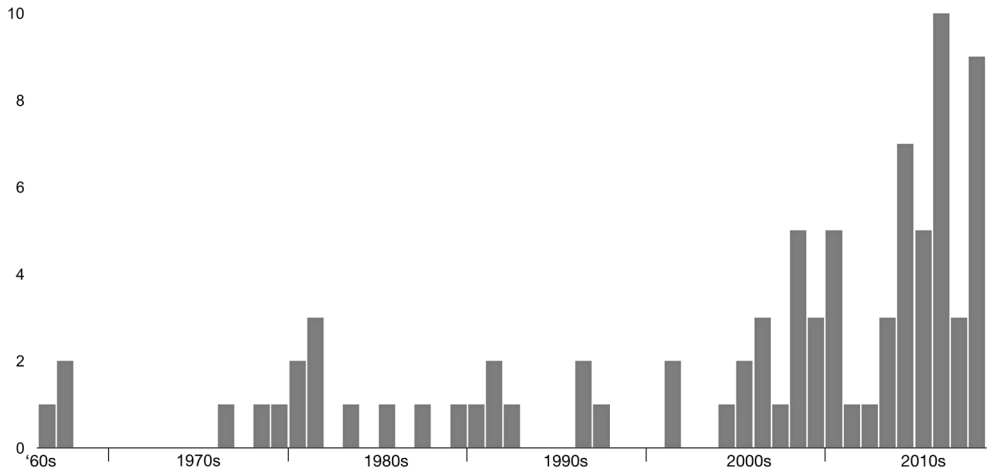

Fig. 3 Number of centers performing transclival approaches during time. Graphic rendering of papers published by authors from different centers, from 1967 to 2018, reporting their experience with extracranial transclival approaches

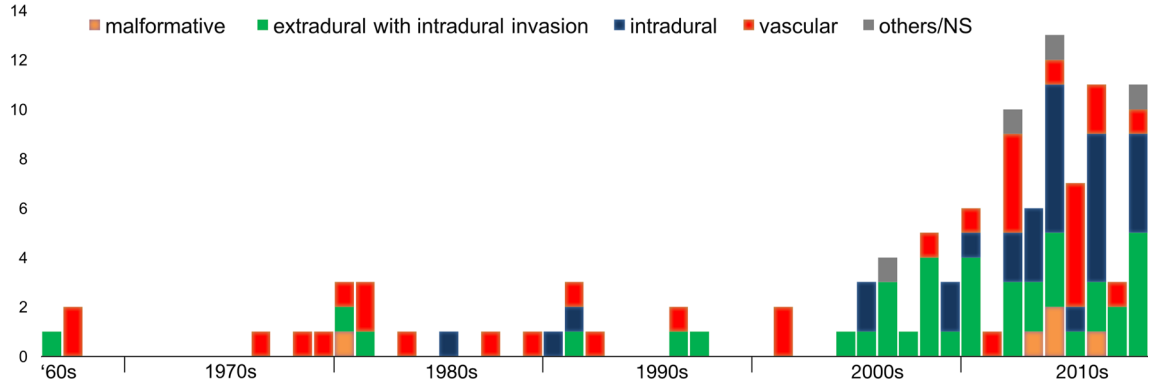

Fig. 4 Evolution of surgical indications to treat different pathologies with transclival approaches during time. Graphic rendering of the number of centers reporting on anterior, extracranial, transclival approaches for each pathology, from 1967 to 2018. Different colors indicate the treated pathologies that involved the intradural space. NS, not specified

two decades, mostly regarding aneurysms. The explanation for this might be the increasing indications for endovascular treatment of posterior circulation aneurysms. A recent detailed review by Di Somma et al. of the ventral route to intracranial aneurysms provides a detailed historical account for this pathology [97]. Reports of transclival approaches for cranio-

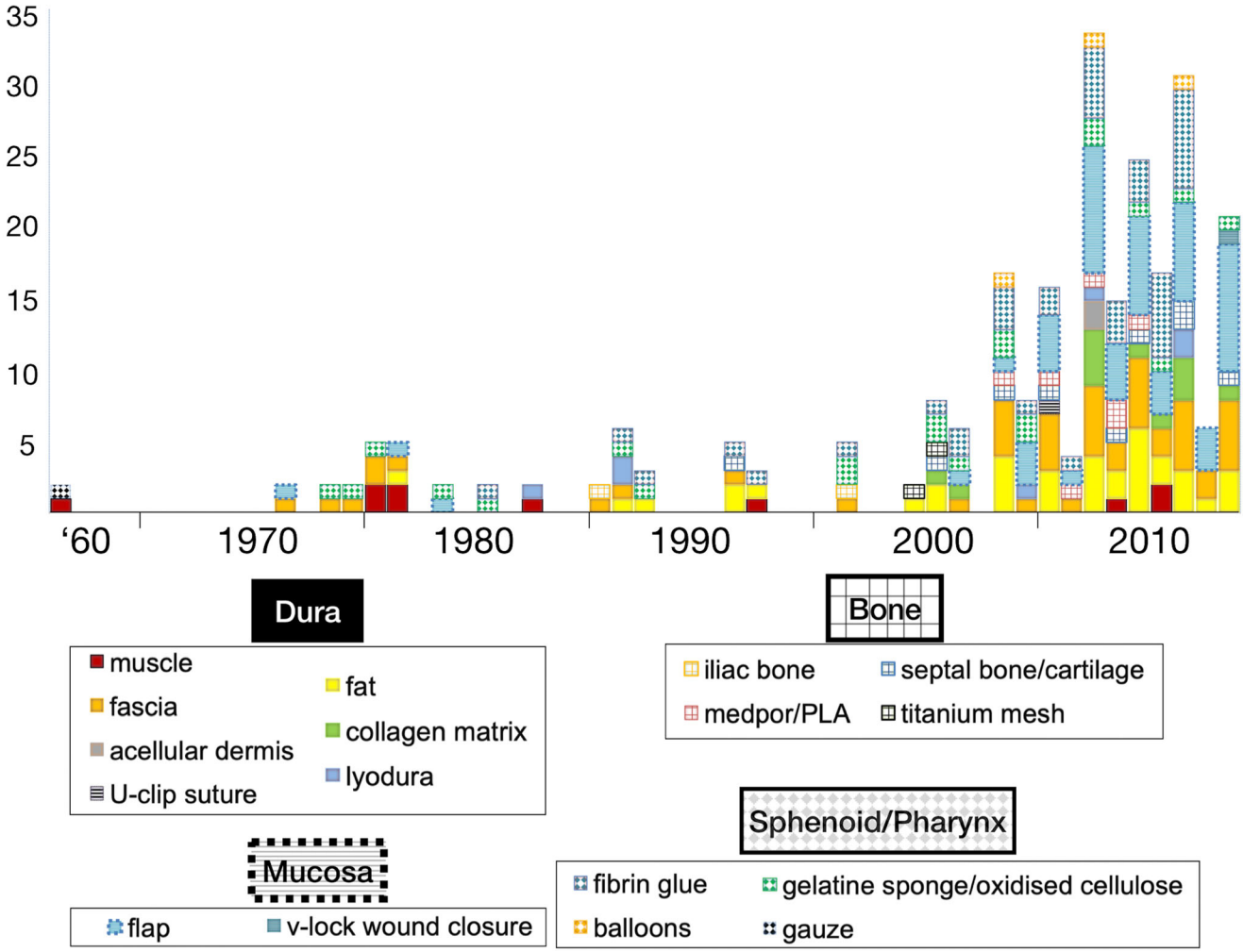

Fig. 5 Reported reconstruction materials for defects after transclival approaches during time. Graphic rendering of the various materials that have been used for clivus reconstruction. Reported materials are subdivided according to the normal structure targeted for reconstitution (i.e., they aimed at reconstituting: dura (full color), bone (filled with horizontal and vertical stripes), mucosa (filled with horizontal stripes, dashed borders), sphenoid and pharynx (filled with rhomboid shapes)). PLA, poly-lactic acid

vertebral junction malformations can be found mostly in the literature during the last decade [62, 67, 68, 88]. In addition, some cases of post-traumatic CSF leaks have also reported [49, 62].

Reconstruction material and techniques

The main challenge of transclival approaches for intradural pathologies is achieving effective skull base reconstruction, with the aim of preventing post-operative CSF leak [98]. In the first reports, autologous materials, such as muscle and fascia [11, 21, 25, 27, 30], together with mucous flaps from rhinopharynx or mucoperiosteal flaps from nasal septum, were used (Fig. 5) [19, 22, 25, 27]. Some authors reported the use of different synthetic materials, including surgical gauzes [11]. Furthermore, iliac bone grafts have been used as a rigid buttress [23, 24]. In the following years, reconstructive materials and techniques followed the same increasing trend of surgical approaches, in particular following the increase of the endoscopic transnasal approach. Indeed, from 2005, a progressively greater number of investigations reported reconstruction with flaps, fat, and fascia (Fig. 5). A similar increase in the use of fibrin glue was observed (Fig. 5). Since the beginning of the 2000s, a growing use of lyodura or collagen matrix and septal bone or cartilage was also seen [23, 24, 33, 40, 41, 43, 48, 55, 57, 58, 61, 63, 71, 79, 80, 83, 84, 88]. The use of oxidized cellulose and gelatin sponge has been reported almost constantly over time [19, 38, 48–50, 55, 65, 67, 70, 83].

The use of lumbar drainage (LD) is suggested by some authors, especially in cases of significant intraoperative CSF leaks. Its use has grown during time, especially after the development of extended endoscopic skull base approaches. A recent paper by Zwagerman et al. [98] reported the results of the first perspective study on LD positioning after performing dural openings via endoscopic transnasal approaches. LD was found to reduce postoperative CSF leaks, especially in the setting of large dural defects associated with anterior and posterior fossa pathologies [98]. Even so, CSF leak remains a significant issue with reported rates of 12.5% for transclival approaches with multilayer reconstruction and LD [98]. From the collected data, considering only case series with at least 10 patients, the mean post-operative CSF leak rate was 16.5% (median 11.6%; range 0–57) [35, 38, 41, 42, 44, 46, 49, 50, 53, 61, 62, 67, 68, 73, 85, 87, 88].

Present and near-future scenarios

The ideal reconstruction after transclival surgery should be as water-tight as possible and provide a rigid buttress against chronic CSF pulsations. At present, the best result is obtained with a variable combination of collagen sponge, fat, fascia, and fibrin glue, covered with a pedicle flap. In theory, taking into account the pressure of the CSF in the posterior fossa on the skull base, a rigid buttress might be useful to contrast its pulsation and to improve the efficacy of reconstruction. At present, this is usually achieved with cartilage or other material, but it is recognized that the geometrical complexity of the clivus renders reconstruction challenging [46].

Though it was not the aim of the present paper, an emerging production technology, additive manufacturing (AM), could provide new and effective solutions for reconstruction of the skull base with synthetic materials [99–115]. This technology allows the production of parts with a high geometrical complexity, which can be modeled and customized based on the patient's anatomy starting from medical imaging. Furthermore, extensive research activities are leading to the development of biomaterials with improved functionalities for bone repair [116–118]. The possibility to combine the multifunctional properties of biomaterials with the geometrical complexity achievable by AM techniques for the production of scaffolds for tissue engineering approaches is highly relevant in this regard [108, 119, 120].

Limits of the study

The inhomogeneity of data reported by different authors allows for only a descriptive comparison and a definition of trending approaches in clinical practice. Furthermore, these approaches are also dissimilar in different centers. Therefore, the best, or at least uniformly shared, technique must still to be defined.

The reported incidence of post-operative CSF leaks is affected by several issues, mainly: all cases of intradural pathologies were necessarily associated with dural opening; some of the older investigations did not report CSF leak rates; some authors did not extensively describe the reconstruction technique; many papers reported highly heterogeneous pathologies; some reconstruction techniques were only reported in case reports; and the results of different reconstruction techniques, in terms of CSF leaks after reconstruction, have not been systematically reported.

Conclusions

Transclival approaches have a long history for treatment of intradural pathologies, characterized by relatively brief parabolas. We are witnessing a significant era of enthusiasm for the first time thanks to the introduction of the endoscope and the development of transnasal skull base surgery. The endoscopic transclival approach remains challenging when dealing with intradural lesions in terms of reconstruction and avoidance of post-operative CSF leaks, especially if large osteo-dural defects are present. The increasing number of centers and reports dealing with this topic, together with newly available

technologies, has the potential to bring about further perfection of the approach and its standardization.

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Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest.

Ethical approval No ethical approval was needed for the study.

Informed consent No informed consent was needed for the study.

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