Vascular complications in transsphenoidal surgery

Complicações vasculares na cirurgia transesfenoidal

Edward R Laws¹
Paulo Henrique Aguiar²

ABSTRACT

Objectives: Vascular complications can and do arise from transsphenoidal surgery and, when occur, they have a high incidence of mortality and serious morbidity. The anatomic substrate for such complications is discussed, along with technical aspects of surgery and other methods for the avoidance of vascular complications. The aim of this paper is discuss the main vascular complications of transsphenoidal approach.

Methods: The authors retrospectively analyzed the data regarding 4175 pituitary transsphenoidal operations from 1974 to 2004.

Results: Thirty-four (34) patients (0.8%) developed direct vascular complications from transsphenoidal surgery. Nine (0.2%) of these were fatal.

Conclusions: Intra-operative injury of the carotid artery is predominately associated with microadenomas, basilar perforator injury may be associated with invasive macroadenomas and anterior cerebral artery injury may be associated with suprasellar tumors. Regarding outcomes, injury of anterior circulation vessels shows relatively low morbidity and mortality, and injury to posterior circulation vessels shows relatively high morbidity and mortality.

Key-words: Pituitary tumors, transsphenoidal approach, basilar artery, vascular complications, pseudoaneurysm, carotid-cavernous fistula.

SUMÁRIO

Objetivos: Os autores discutem os fatores que interferem nas complicações vasculares do acesso transesfenoidal para tumores hipofisários. Procuram entender as causas e as relações entre os tipos de tumor, tamanho e as lesões arteriais por região.

Casuística e Método: 4175 cirurgias transesfenoidais realizadas pelo autor principal no período de 1974 à 2004 foram analisadas quanto a incidência, tipo e causa de lesão vascular.

Resultados: Trinta e quatro pacientes desta casuística, apresentaram lesão vascular relacionada ao procedimento cirúrgico, sendo fatal em 9 casos. Microadenomas apresentaram relação com lesão da artéria carótida e macroadenomas com lesão da artéria basilar, bem como adenomas com extensão suprasellar com lesões da artéria comunicante anterior.

Conclusão: Dados como cirurgia prévia, localização e extensão tumoral são importantes para se predizer uma complicação vascular. O seu tratamento depende da rapidez com que há o tamponamento arterial, mas também da viabilidade de termos procedimentos endovasculares de emergência. Doppler intraopeartório, neuronavegação e ressonância intra-operatória podem ser úteis para se evitar a lesão arterial. As vias minimamente invasivas, como acesso endoscópico endonasal, parecem ter um papel importante para se minimizar as complicações.

Palavras-chaves: Tumor hipofisário, acesso transesfenoidal, pesudoaneurisma de artéria carótida, complicação vascular.
INTRODUCTION

Vascular complications during or after transsphenoidal surgery are rare, but when they occur can produce a high incidence of mortality and morbidity.

Significant advances in the recognition and management of pituitary adenomas has taken place over recent decades[14]. Highly sensitive hormonal assays and magnetic resonance imaging with gadolinium enhancement have led to earlier and more frequent diagnosis of pituitary adenomas[14].

The microscopic transsphenoidal approach for pituitary tumors has demonstrated excellent results with minimal morbidity and almost no mortality; and has become the therapy of choice for the majority of pituitary adenomas[14,22,38,57,59,60]. Continued attempts to improve surgical outcomes, reduce the incidence of complications, and hasten post-operative recovery have led to the development of a minimally invasive fully endoscopic transsphenoidal approach to remove pituitary adenomas.

Hirch’s original endonasal rhinoseptal route[6,7,8,33,42,43] was later modified. It avoids an anterior nasal or sublabial incision, requires no anterior dissection through nasal or sublabial incision, no anterior dissection of the nasal septum is necessary, and it requires only minimal dissection of the posterior nasal mucosa. This approach “per si “ is better tolerated , with less postoperative pain, than the more traditional sublabial or rino-septal routes.

The most common vascular complications described in literature are carotid occlusion, carotid stenosis, carotid pseudoaneurysm, sphenopalatine false aneurysm, middle cerebral artery occlusion, anterior cerebral artery occlusion and rupture, basal artery compression and rupture, carotid cavernous fistula[7,13,40,46].

The aim of this study is to evaluate the incidence of intraoperative vascular injury during transsphenoidal surgery.

ANATOMIC AND TECHNICAL ASPECTS OF THE TRANSSHENOIDAL APPROACH

The sella has its limits which are well known. From above the limits are the optic nerves and chiasm, as well as the circle of Willis. Laterally they consist of the cavernous sinuses, and internal carotid arteries. Posteriorly, they are the clivus, basal artery and brainstem[17].

The initial aspects of the traditional approach are through the mucous membranes of the nose and the undersurface of the lip. These membranes can often be quite vascular, with numerous small interconnecting vascular channels, and bleeding can be considerable if no attempt is made to produce decongestion and hemostasis. Rhinologic surgeons have used a number of techniques to avoid this type of bleeding.

The paired sphenopalatine arteries, branches of the internal maxillary artery, supply the nasal structures, which should be avoided. Ordinarily, the midline approach will not disturb the main trunks of the sphenopalatine arteries and every attempt during the approach should be made to avoid injury to these vessels.

The carotid arteries and their bony canals lie on either side of the sphenoid sinus. Theses canals need to be identified carefully and injury or entrance into them obviously should be avoided as the sella is exposed[60].

The cavernous portion of the carotid artery is vulnerable to damage during the exposure of the sella. The cavernous carotid may be quite tortuous and the carotids, in some cases can actually come in contact centrally within the sella. These arterial segments can also be quite atherosclerotic, particularly in patients with acromegaly, and they may lie just behind the dura where they are vulnerable to injury during the opening of the sellar dura and exposure of the pituitary lesion.

The cavernous sinuses on either side of the sella are vascular structures filled with venous blood under venous pressure. The two cavernous sinus frequently connect through dural channels, most commonly the superior and inferior intercavernous sinuses. These connecting channels can be injured during the opening of the dura. The dura itself consists of two layers and between these layers vascular channels commonly proliferate, particularly in the normal sella or one that harbors a microadenoma. The removal of the lesion may also lead the surgeon directly into the cavernous sinus. It is important to remember that in addition to the carotid artery the third, fourth, fifth and sixth cranial nerves are intimately associated with the cavernous sinus, and are therefore subject to surgical injury. As with other venous channels, if the head of the patient is raised above the level of the heart, there is a potential for air embolus into the interconnecting veins or directly into cavernous sinus. Venous air embolism can be detected when careful anesthetic monitoring is done, but we have not experienced clinical consequences of air embolism in our patients.

A number of specific vessels have been described that commonly supply lesions occurring in and around the sella turcica. The most important of these is the meningohypophyseal trunk which gives rise to important arterial vessels supplying the pituitary gland and the pituitary stalk. This vessel can also proliferate to provide vascular supply to pituitary lesions. Above the diaphragm, there is a circuminfundibular plexus that likewise can elaborate to feed pituitary lesions. There are several so-called capsular arteries that arise from the cavernous carotid and
ordinarily supply the sellar dura and can also proliferate to feed pituitary lesions.

All of these vessels have the potential of causing technical difficulty when dealing with lesion directly.

Just above the diaphragm of the sella is the circle of Willis, and its relationship to the dorsal aspect of variety of pituitary lesions can place it at risk for significant damage. The surgeon should carefully consider the anatomy of the Circle and its integrity with regard to collateral flow.

Hypothalamic damage may occur from vascular injury or direct trauma.

Immediately behind the clivus lies the basilar artery with its branches. Some lesions that destroy the clivus can make this vessel vulnerable to injury and a misdirected approach through the clivus rather than through the floor of the sella can also injure the basilar vessels.

**METHODS**

Retrospectively the personal series of the senior author was reviewed consisted of 4175 consecutive transsphenoidal operations between 1972 and 2004 to determine incidence, causes, and management of vascular complications.

**RESULTS**

A Thirty four (34) patients (0.8%) developed direct vascular complications from transsphenoidal surgery. Nine (0.2) of these were fatal. The data are summarized in the table I.

<table>
<thead>
<tr>
<th>Table I - Vascular complications</th>
<th>Fatal</th>
<th>Non-Fatal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carotid artery injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22 patients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• pseudoaneurysm</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>• carotid artery thrombosis</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>• during treatment wall laceration</td>
<td>1</td>
<td>12 (8=direct repair &amp; 4=PBO)</td>
</tr>
<tr>
<td>Anterior Cerebral Artery 4 patients</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Basilar artery and perforations 8 patients</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Total (34)</td>
<td>9</td>
<td>25</td>
</tr>
</tbody>
</table>

**INTERNAL CAROTID INJURY**

Injury of the internal carotid artery were associated with microadenomas in 18 patients in a total of 22 cases (81%). Figure 1 shows the CT scan of a patient with intracranial bleeding after a carotid injury, and Figure 2 shows an angiogram of a patient harboring an ACTH microadenoma surgically treated by transsphenoidal surgery, which resulted in pseudoaneurysm of the right carotid artery. Fourteen of these patients had previous surgery (64%). Invasion of the cavernous sinus by the tumor was found in 12 (55%).

![Figure 1](image1.png)  
**Figure 1** – CT scan – A(left) - hematoma in interpeduncular fossa. B(Right) intraventricular hematoma.

![Figure 2](image2.png)  
**Figure 2** – Digital subtraction angiogram shows a pseudoaneurysm of the right carotid artery after transsphenoidal approach for a 33 years-old patient with Cushing’s syndrome.
BASILAR ARTERY PERFORATOR INJURY

Lesions of basilar artery were associated with invasive macroadenomas which were adjacent and adherent to basilar perforators in 8 patients. There were 7 tumors with suprasellar extension (88%). Previous surgery had been done in 4 of 8 (50%).

ANTERIOR CEREBRAL ARTERY INJURY

Injuries to the anterior cerebral artery were associated with macroadenomas evolving adjacent to suprasellar structures, 4/4 (100%). Suprasellar extension of tumour had occurred in 4/4 (100%). An extended transsphenoidal approach was done in 3/4 of patients (75%).

DISCUSSION

Victor Horsley in 1889, using a transcranial approach is credited with performing the first operation for a pituitary tumor. In 1906 Schloffer reported the first removal of a pituitary tumor through an extracranial transsphenoidal approach. Hirsch later modified this approach in 1909. In 1912, Cushing described the transseptal transsphenoidal approach to the sella turcica. Guiot and Hardy refined the technique and added intraoperative fluoroscopic guidance and the use of the surgical microscope. Since then, the approach has become the standard for lesions of the sella and those extending in the midline in a suprasellar direction. The complications of the approach are well described and include septal perforation, septal deviation, tearing of the nares, persistent nasal discharge, recurrent nosebleeds, tooth analgesia, asymmetry of mucosal contour, sinusitis, and mucocele among others.

It wasn’t until the late 1950’s that Guiot who learned Cushing’s transseptal-transsphenoidal method from Norman Dott, reintroduced this approach. Guiot improved the transsphenoidal approach with the addition of intra-operative fluoroscopy to guide the insertion of instruments into the sella, allowing for safer and more complete tumor removal. It is Hardy, however, who deserves much of credit for reestablishing the validity of the transsphenoidal approach, when in the 1960’s he combined fluoroscopy and microsurgical techniques to further augment transsphenoidal pituitary tumor resection.

These new technologies provided the transsphenoidal approach with significant advantages over the transcranial procedure. The improved visualization, allowed for more complete tumor removal, and reduced the incidence of complications. In the ensuing 40 years several large series have established the transsphenoidal approach as the procedure of choice for all but the most massive pituitary adenomas, demonstrating outcomes equivalent or better than those reported for the transcranial procedure with fewer complications.

The use of rigid endoscopes for sinus surgery provided the inspiration for their application to pituitary surgery. Currently, endoscopic surgery is a safe and accepted method of sinus surgery. Stankiewicz has described an endoscopic approach to the sphenoidal sinus. Building on this experience, otolaryngologists have reported pituitary tumor resection aided by endoscopic techniques.

Complications in transsphenoidal pituitary surgery are typically related to blind dissection, inability to determine normal gland from tumor, injury of the optic tracts and chiasm, or aggressive tumor dissection near the lateral and posterior aspects of the sella turcica.

Improved visualization allows the surgeon to identify and avoid injury to the normal pituitary gland, carotid prominences, hypothalamus, and optic chiasm or bulbs. Recognizing these structures during pituitary tumor removal is critical to avoid catastrophic complications, which have been reported in several microscopic series.

The incidence of vascular complications in the largest series based on literature ranged from 0.2% to 1.5%. The mortality of the patients who presented vascular complication after transsphenoidal surgery reached 100% in some series. Figure 3 shows a huge hematoma in a patient treated surgically for a macroadenoma with suprasellar extension (autopsy specimen).

Figure 3 – Autopsy specimen (sagital view) Department of Neurology, São Paulo Medical School. Forty-five years-old male patient harboring a macroadenoma with suprasellar extension treated by a transsphenoidal approach: after recovering from anesthesia, the patient developed a sudden coma and died in a few hours.
As the number of the cases increased in the past 30 years, we observed an increase in the rate of vascular complications, however in a velocity lower than the increase of the number of surgically treated patients. In 1982, we published 810 cases with a rate of vascular complications of 0.4%, in 1999, 3061 cases with 0.78% and in the present study, 2004 cases, with 0.9% of complications.37,40 Table II and III show the previous publications and their incidence of vascular complications as well as number of fatal cases. Table IV shows the incidence of rebleeding after transsphenoidal surgery which ranges from 0.3% to 1.2%.5,13,17,37,44,59.

### Table II - Incidence of vascular complications (literature review)

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Patients</th>
<th>Incidence%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kautzky &amp; Lüdecke</td>
<td>1978</td>
<td>2/130</td>
<td>1.5%</td>
</tr>
<tr>
<td>Wilson &amp; Dempsey</td>
<td>1982</td>
<td>3/810</td>
<td>0.4%</td>
</tr>
<tr>
<td>Fahlbusch</td>
<td>1994</td>
<td>3/1688</td>
<td>0.2%</td>
</tr>
<tr>
<td>Raymond &amp; Hardy</td>
<td>1997</td>
<td>24/2004</td>
<td>1.2%</td>
</tr>
<tr>
<td>Laws</td>
<td>1999</td>
<td>24/2004</td>
<td>1.2%</td>
</tr>
<tr>
<td>Kanter</td>
<td>2005</td>
<td>1/33</td>
<td>0.4%</td>
</tr>
<tr>
<td>Present study</td>
<td></td>
<td>34/4175</td>
<td>0.8%</td>
</tr>
</tbody>
</table>

### Table III - An overview of mortality after transsphenoidal surgery

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Patients</th>
<th>Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guiot &amp; Derome</td>
<td>1976</td>
<td>613</td>
<td>1.4%</td>
</tr>
<tr>
<td>Fahlbusch &amp; Stass</td>
<td>1981</td>
<td>601</td>
<td>1.2%</td>
</tr>
<tr>
<td>Hardy &amp; Mohr</td>
<td>1985</td>
<td>1102</td>
<td>0.9%</td>
</tr>
<tr>
<td>Laws</td>
<td>1982</td>
<td>250</td>
<td>0.5%</td>
</tr>
<tr>
<td>Landolt</td>
<td>1985</td>
<td>496</td>
<td>0.9%</td>
</tr>
<tr>
<td>Tindall &amp; Barrow</td>
<td>1986</td>
<td>240</td>
<td>1.2%</td>
</tr>
<tr>
<td>Fahlbusch</td>
<td>1994</td>
<td>1688</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

Kai et al.23 report on a case of a patient who suffered a pseudo internal carotid artery (IC) aneurysm following transsphenoidal surgery. He was successfully treated with bypass surgery and IC occlusion involving the pseudoaneurysm using Guglielmi detachable coils (GDCs). Another patient treated by Kobayashi et al.,29 developed a traumatic carotid cavernous fistula (CCF) caused by transnasal-transsphenoidal surgery, and was successfully treated using detachable coils. They suggested that drilling is a safer procedure than using a chisel for dissection of a sphenoid sinus with incomplete pneumatization and that endovascular treatment using detachable coils proved useful to manage the carotid cavernous fistulae, an unusual complication of transsphenoidal surgery.

To avoid arterial lesions, perfect understanding of anatomical structures and their relation is very important. Also, the use of an endoscopic approach may provide safe and more minimal invasive surgery. During dissection of large pituitary tumor, a mini doppler is useful before incising the dura.2,61. Yamazaki et al.61 described an intraoperative use of pulsed Doppler ultrasound in transsphenoidal surgery to prevent mechanical vascular injury, particularly to the intracavernous portion of the internal carotid artery. This system is integrated by connection to a video processor. They emphasize that the use of Doppler sonography provided real-time measurement of arterial or venous flow velocity and source of flow by both real-time sonograms and sound frequencies. With the use of a microprobe, 1mm in diameter, vessels located within 7mm from the tip of the probe could be easily, rapidly, and noninvasively detected, without disturbing the operative field. Other important advantage of this Doppler is that both the size and the distance of a vessel could be measured by turning the dial of Doppler signal gain from initially waxing to waning Doppler sounds, because the acoustic sounds were adjusted to the axial flow of each vessel in 0.1-mm increments61.

The preoperative imaging studies is helpful to plan the access, and the position between bone and arteries in the sellar proximities.
Previous surgery requires meticulous evaluation of imaging studies, and historical records in order to identify any prior intraoperative bleeding and even minor hemorrhage. Prior arterial injury has to be considered, especially in Cushing’s disease patients.

Raymond et al, 1997 concluded that profuse bleeding during and after transsphenoidal surgery should be investigated by angiography. Lesions of the sphenopalatine arteries are effectively treated by embolization. Internal carotid injuries are best treated by carotid occlusion to prevent life-threatening epistaxis. In their retrospective study of the arterial hemorrhagic complications, their management, and the clinical outcomes that occurred in 21 of the more than 1800 patients who had transsphenoidal surgery for pituitary adenomas were assessed. Of the 21 patients who had complications, 17 had internal carotid injuries and four had injuries of the sphenopalatine artery.

Angiography was performed in 18 patients. Bleeding occurred and was controlled during surgery in 16 cases. Delayed epistaxis occurred in 10 patients, including five whose surgery was uneventful. After internal carotid injury, the most frequent angiographic findings were carotid occlusion (eight patients), stenosis (five patients), and false aneurysms (three patients). Internal carotid balloon occlusion was performed in five patients. No rebleeding occurred in patients who had complete carotid occlusion either from surgical packing or balloon embolization. Two of the patients who had carotid stenosis after surgical packing had delayed epistaxis necessitating balloon occlusion. Injuries to the sphenopalatine artery were successfully treated by surgery (one patient) or by endovascular treatment (three patients) without complication. Three deaths and five permanent deficits were directly related to the arterial injury or its treatment. Our series shows similar incidence. They listed a series of predisposing factors or surgical events before the vascular complication: nonpneumatized sphenoid, multiple sphenoidal septa, oblique sphenoidal septa, tumor adherent to carotid artery, acromegalic changes, cavernous sinus invasion, cavernous aneurysms, sphenopalatine avulsion during the opening and bleeding difficult to control during the opening.

Kurschel et al, 2005 reported a case of a 61-year-old man, who underwent transsphenoidal surgery for a pituitary macroadenoma. The presence of tough fibrous septa dividing the tumor permitted only a partial resection. Progressive loss of consciousness soon after surgery occurred, an emergency CT scan showed no evidence of hemorrhage. Twenty hours later, MRI revealed compression of both internal carotid arteries with arrest of arterial flow resulting in stroke caused by an enlarging hemorrhagic mass consistent with pituitary apoplexy. On the second postoperative day, the patient died as a result of this extensive stroke.

Barker et al, 2003 studied the data from 5497 operations performed in the United States during the period from 1996 to 2000, performed by 825 surgeons at 538 hospitals. The records regarding mortality and morbidity were sampled and compared with Hospital and surgeon volume 3. Outcome measured at hospital discharge was death in 0.6%, discharge to long term care (0.9%), to short term rehabilitation (2.1%) or directly home 96.2%. Outcomes were better after surgery in higher volume hospitals (OR 0.74 for 5-fold larger caseload, p=0.007) or by higher volume surgeons (OR 0.62, p=0.02). A total of 5.4% of patients were not discharged directly home from lowest volume-quartile hospitals, compared with 2.6% at highest volume-quartile hospitals. In-hospital mortality was lower with higher volume hospitals (p=0.03) and surgeons (p=0.09). Mortality rates were 0.9% at lowest-case load–quartile hospitals and 0.4% at highest volume quartile hospitals. They demonstrated that postoperative complications (26.5% of admissions) were less frequent with higher – volume hospitals (p=0.03) or surgeons (p=0.005). Length of stay was shorter with high volume hospitals (p=0.02) and surgeons (p<0.001). Also, the hospital charges were lower for high volume hospitals, but not significantly. Finally, they concluded this analysis suggests that higher volume hospitals and surgeons provide superior short term outcomes after transsphenoidal pituitary tumor surgery with shorter lengths of stay and a trend toward lower charges.

The closure of sellar floor should be meticulous. Sometimes the best solution is using fat, or considering reconstruction of the sellar dura in transsphenoidal surgery using an expanded polytetrafluoroethylene dural substitute. Videofluoroscopy has served to provide intraoperative guidance, for many decades, however, frameless stereotaxy with archived computed (CT) or magnetic resonance imaging (MRI) exploits the concept of neuronavigation to its fullest. Frameless stereotaxy allows precise planning of the approach with reference to lesion perimeters, anatomic landmarks such as the carotid arteries, and other potential operative hazards. Frameless stereotaxy is a safe and effective modality for the treatment of recurrent or invasive sellar masses. All three frameless stereotaxy modalities provided accurate information regarding the anatomical midline and the trajectory to the sella turcica. Neuronavigation is particularly helpful in reoperative pituitary surgery where few anatomic landmarks remain. We believe that frameless stereotaxy adds greatly to surgeon comfort and confidence during the procedure. It is extremely important to emphasize that the surgeon using the technique must always remember that the information used is based on navigation points that are prerecorded and are only as accurate as the system allows in a perfectly set-up state. Minor movement in the pin holders results in a disastrous loss of accuracy.

In our opinion intraoperative MRI takes away this reliance on experience and should be a major advance in resection control.
Surgery is performed with the patient lying directly on the table of MRI scanner5. After the endoscopic transsphenoidal or a standard transsphenoidal procedure, an intraoperative MRI is performed while the operative exposure and sterile field are both maintained so that if residual tumor is seen, further resection is undertaken.

REFERENCES


CORRESPONDING AUTHOR

Paulo H. Aguiar, MD.
280 Durand Way 94304, Palo Alto, California, USA or Rua David Bem Gurion 1077, Apto 11, Morumbi, São Paulo, Brazil.
phpaneurocir@gmail.com