Avoidance of Carotid Artery Injuries in Transsphenoidal Surgery with the Doppler Probe and Micro-hook Blades

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ONLINE DIGITAL VIDEO

OBJECTIVE: Internal carotid artery (ICA) injury during sellar dural opening is a potentially catastrophic complication of transsphenoidal surgery. We describe two ICA injuries that occurred early in our endonasal transsphenoidal experience. We then describe our subsequent protocol to prevent this complication in which we use the Doppler probe for carotid localization and micro-hook blades for lateral dural opening.

METHODS: All patients undergoing endonasal tumor removal were analyzed since beginning this approach in 1998. Of 631 procedures (585 patients), three patients sustained an ICA injury.

RESULTS: In the first 114 procedures (105 patients) in which the Doppler probe was not used and hook blades were used infrequently, two (1.8%) ICA injuries occurred. In both cases, a right nostril approach was used and the left ICA was punctured on dural opening with a straight scalpel; both patients recovered without neurological sequelae. In the subsequent 517 procedures in which the Doppler probe and hook blades were used in all cases, one (0.19%) probable ICA injury occurred during an attempted removal of a cavernous sinus schwannoma, although there was no angiographic evidence of vascular injury. There were no ICA or other intracranial vascular injuries in the last 510 procedures for tumors not solely confined to the cavernous sinus.

CONCLUSION: Cavernous carotid localization with the Doppler probe before dural opening and angled hook blades for lateral dural opening can help minimize the risk of ICA injury and are recommended for all transsphenoidal operations. Because of the wider contralateral exposure provided by the endonasal approach, the ICA contralateral to the nostril of approach is at higher risk of injury on dural opening.

KEY WORDS: Carotid artery injury, Complications, Doppler probe, Endonasal approach, Instrumentation, Transsphenoidal surgery

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The transsphenoidal approach for the removal of pituitary tumors and related parasellar pathology is considered an effective and safe procedure, with morbidity and mortality rates typically less than 1% (1, 3, 14, 29, 30, 32, 43). However, one of the most serious complications during transsphenoidal surgery is injury to the cavernous internal carotid artery (ICA), which most commonly occurs during the sellar dural opening and has been reported to occur in 0 to 3.8% of cases (1, 3, 5, 6, 9, 16, 18, 26, 27, 33, 35, 37, 43). This potentially fatal complication is one that all transsphenoidal surgeons should try to avoid but be prepared to manage. Use of the micro-Doppler probe for carotid localization before dural opening (41, 42) and angled hook blades for lateral dural opening are potentially simple and effective surgical adjuncts that can help one avoid an ICA injury, yet have received little attention in the literature. Although our group has discussed the usefulness of the Doppler probe and angled micro-blades in previous reports, we have not presented data on these two techniques (7, 13, 43). Although the direct endonasal approach provides a rhinologically superior patient experience compared with the sublabial approach (14), the surgical trajectory to the sella is slightly off-midline, typically resulting in greater contralateral exposure by 10 to 15% (4, 10, 17, 40). This enhanced angulation can be advantageous to access lateral tumor adjacent to or within the contralateral cavernous sinus; however, it also places the contralateral ICA at increased risk of injury during dural opening (*Fig. 1*). After two such ICA injuries early in our experience with this approach, we instituted a protocol change incorporating the routine use of the Doppler probe and microhook blades to avoid this complication. Rates of ICA injury before and after initiating this protocol and suggestions on how to prevent and manage an ICA injury are presented.

PATIENTS AND METHODS

Patient Population

All patients in the University of California at Los Angeles (UCLA) Pituitary Tumor database who underwent transsphenoidal surgery by the direct endonasal approach (July 1998–April 2006) at UCLA or Harbor-UCLA Medical Centers were included in this retrospective analysis. Those patients sustaining an intraoperative ICA injury were identified and categorized regarding whether the injury occurred before or after the protocol change implementing routine use of the Doppler probe and angled hook blades in July 2001. No other vascular injuries to the circle of Willis vessels occurred in this series. There were four patients with delayed epistaxis secondary to sphenopalatine artery bleeding that occurred 7 to 14 days after surgery; these patients were not included in this analysis. The senior author (DFK) performed all surgeries. All patients had at least one follow-up visit 3 weeks or longer after surgery.

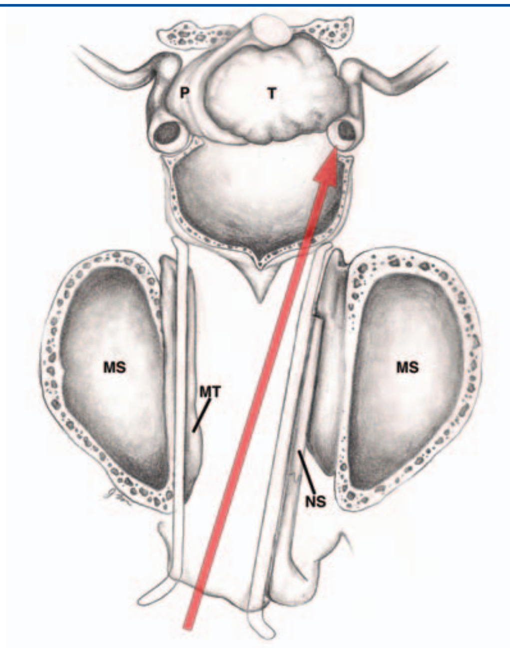


FIGURE 1. *Illustration depicting an axial view of the endonasal approach with the self-retaining speculum in the right nostril and an enlarged sella containing a macroadenoma compressing the pituitary gland to the right and tumor extension to the left cavernous sinus. Note the accentuated leftward exposure of 10 to 15 degrees, which maximizes tumor exposure but increases the risk of injury to the contralateral cavernous ICA. P, pituitary gland; T, tumor; MS, maxillary sinus; MT, middle turbinate; NS, nasal septum.*

Current Surgical Technique

(see videos at web site)

The endonasal approach using the operating microscope for tumor removal has been described in recent studies (7, 13, 14, 43). Relevant details of the procedure are described here. Fluoroscopy is used for trajectory guidance and computerized surgical navigation is used in a minority of select cases. After a wide sphenoidotomy, the bony sella is removed with rongeurs or a drill. The extent of bone removal is guided by the given pathology and whether or not an extended approach is required for suprasellar, planum, clival, retroclival, or cavernous sinus lesions (13). The bony removal is also guided by the intrasphenoidal bony septations observed at surgery and correlated with those identified on the patient's preoperative magnetic resonance imaging scan. For most sellar and suprasellar lesions, the sellar opening extends to the edges of the cavernous sinuses bilaterally, to the sellar floor inferiorly, and to the tuberculum sella superiorly.

Before opening the sellar dura, a bayonetted micro-Doppler probe (10-Mhz ES-100X MiniDop with NRP-10H bayonet probe [Koven, St. Louis, MO] or 20-MHz Surgical Doppler [Mizuho America, Beverly, MA]) is used to insonate for the cavernous ICAs (*Fig. 2*). The probes consist of a 2- to 2.5-mm diameter, pulsed-wave Doppler with 0-degree angle of insonation and a beam width of approximately 1 × 1 mm. The probes generate high-frequency oscillation in an emitting and receiving piezoelectric crystal, in which they are converted to ultrasound and transmitted to the vessel. Some of the energy is reflected back from the moving red blood cells with changes in frequency inherent in the Doppler shift principle. The converted signals are amplified and supplied to a phase wave detection circuit and converted to an audio signal by a central processing unit.

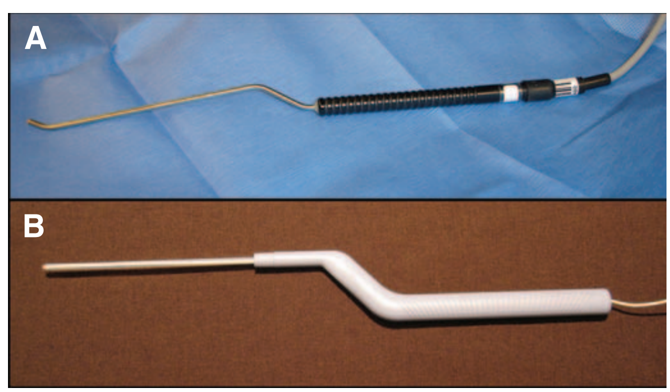


FIGURE 2. *Photographs of bayoneted micro-Doppler probes used for localization of cavernous ICA before sellar dural opening.* A, *Koven micro-Doppler probe.* B, *Mizuho micro-Doppler probe.*

To localize the cavernous ICAs, the probe is initially placed at the edge of the bony opening at 90 degrees to the dura (*Fig. 3*). If only faint or no audible flow is present, the probe is angled more laterally, aiming out under the bone edge; in most cases, ICA flow will become apparent or louder. The probe is then moved superiorly and inferiorly to determine whether or not the ICA comes more medially or laterally in the superior and inferior extents of the exposure. If no Doppler flow is evident, additional bone can be removed laterally to maximize sellar exposure. If audible flow is still not evident, consideration should also be given to whether or not there is a technical problem with the probe, which can occasionally occur.

A wide sellar dural opening is then performed, typically in a U-shaped fashion, avoiding the area of greatest audible Doppler flow (*Fig. 4*). This initial opening is performed with a straight feather microblade (Synovis Surgical Innovations, St. Paul, MN), attached to a bayoneted handle (*Fig. 5*). This low-profile instrument minimizes visual obstruction within the speculum to the sellar dura compared with a standard No. 11 scalpel blade and handle. After the initial dural opening, angled microdissectors are used to separate the dura from the underlying tumor or normal pituitary gland. The dural opening is then enlarged superiorly and laterally as needed with the use of a right angle micro-blade, which allows the cutting force of the blade to be directed away from the sellar and cavernous sinus structures. Tumor removal and closure of dural and bony defects then proceeds in standard fashion, as previously described (23, 43).

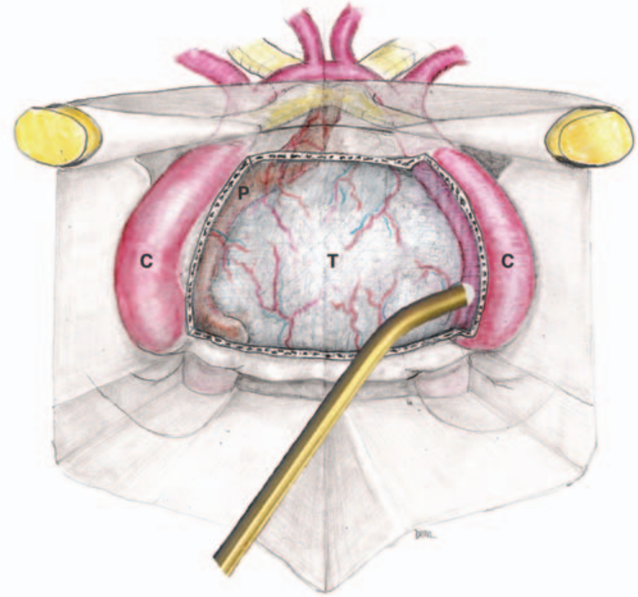


FIGURE 3. *Illustration depicting a view of the sella containing a macroadenoma as seen from a right endonasal approach. The sellar bone has been removed and, as is often the case, the contralateral bone removal on the left is somewhat more extensive than on the right, leaving the medial edge of the left cavernous ICA exposed. The micro-Doppler probe is being used to localize the left cavernous ICA and to guide the appropriate location for dural opening. C, cavernous ICA; P, pituitary gland; T, tumor.*

RESULTS

Cohort Characteristics

From July 1998 to April 2006, 585 patients (60% women; age range, 5–85 yr; median age, 47 years) underwent endonasal surgery for tumor removal, for a total of 631 operations (*Table 1*). Of these, 545 (93%) patients had one surgery, 36 patients had two surgeries, and four patients had three or more surgeries; 15% of patients had a previous operation elsewhere and had repeat surgery for residual tumor or tumor recurrence. An extended transsphenoidal approach to the suprasellar space, clivus, retroclival space, or cavernous sinus was used in 67 procedures.

Incidence of ICA Injury

Three (0.48%) of 631 procedures had an intraoperative ICA injury; two occurred in the first 105 patients (114 procedures), for an injury rate of 1.8% per procedure. In the subsequent 480 patients (517 procedures) in which the micro-Doppler probe and the micro-hook blades were used in all cases, one ICA injury occurred, for an injury rate of 0.19% per procedure (P = 0.086, Fisher's exact test). There were no ICA or other intracranial vascular injuries in the last 510 procedures for sellar, suprasellar, clival, or retroclival tumors that were not solely confined to the cavernous sinus.

Illustrative Cases

In the first two patients (Patients 73 and 105), one of whom had acromegaly and the other Cushing's disease, the micro-Doppler probe

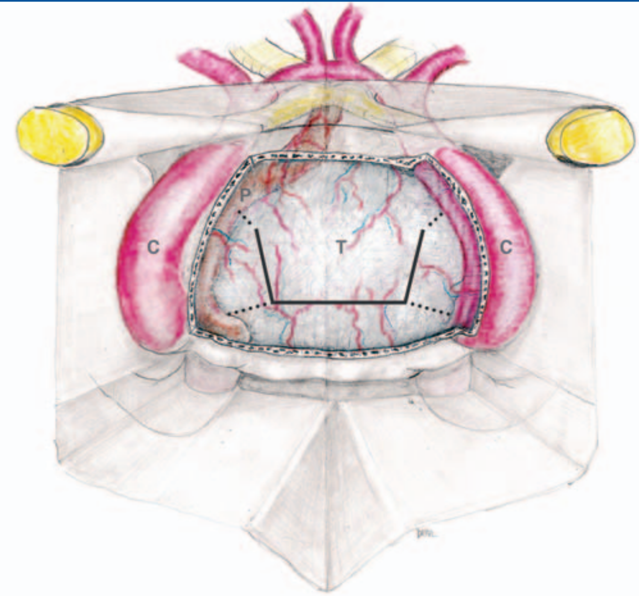
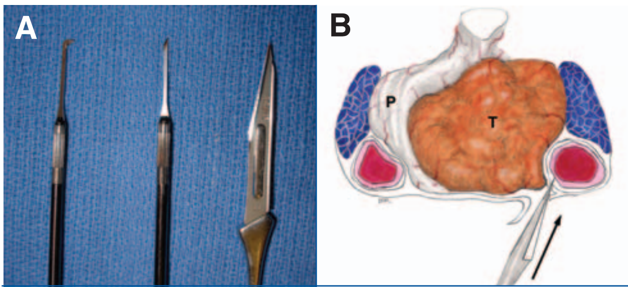


FIGURE 4. *Illustration demonstrating the initial sellar dural opening in a U-shaped fashion (*solid line*), which is performed with a straight microblade as shown in Figure 5, and the subsequent lateral dural openings (*dashed lines*) that may be used for additional exposure, which should be performed with a right-angled micro-hook blade or angled microscissors. C, cavernous ICA; P, pituitary gland; T, tumor.*



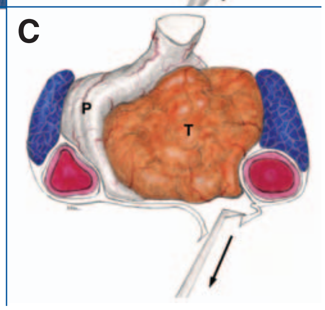


FIGURE 5. A, *compared with a traditional No. 11-blade scalpel on a bayoneted handle (on the* right*), the low-profile bayoneted straight and micro-hook blades afford improved visualization during sellar dural opening in the restricted working space of the endonasal speculum.* B, *opening the lateral sellar dura with a straight micro-blade or scalpel risks injury to the cavernous ICA.* C, *opening the lateral dura with the angled micro-hook blade allows the cutting force to be directed toward the surgeon (*arrow*), rather than toward the cavernous sinus and ICA. P, pituitary gland; T, tumor.*

TABLE 1. Pathological diagnoses of 586 patients undergoing transsphenoidal surgery[a]

Pathology	No. of patients
Pituitary adenoma	447
Endocrine inactive	246
ACTH secreting (Cushing's disease)	81
Prolactinoma	70
GH secreting (acromegaly)	48
TSH secreting	2
Non-adenomatous lesions	138
Rathke's cleft cyst	44
Craniopharyngioma	21
Chordoma/clival mass	20
Meningioma	18
Other parasellar tumors	35

[a] ACTH, adrenocorticotropic hormone; GH, growth hormone; TSH, thyroid-stimulating hormone.

and hook blades were not used. In both cases, a right nostril approach was used and the left ICA was injured on dural opening with a straight scalpel blade. Bleeding was initially controlled with Gelfoam (Upjohn Co., Kalamazoo, MI) and cottonoids; repair was performed with two layers of muslin gauze followed by fibrin glue and, in one case, a fat graft. Both patients had an emergent cerebral angiogram while still intubated. The first patient sustained a left ICA pseudoaneurysm treated endovascularly with detachable coils. Her magnetic resonance imaging scan revealed a small left occipital infarction; however, she remained neurologically intact but had persistent acromegaly. The second patient had a complete left ICA occlusion but with good collateral circulation. Her magnetic resonance imaging scan showed no hemorrhage or ischemia and she remained neurologically intact, although her Cushing's disease persisted.

The third probable ICA injury occurred in a 71-year-old woman (Patient 413) with intractable facial pain from a 2.8-cm trigeminal schwannoma. She underwent operation for tumor debulking through a left endonasal approach. After the right aspect of the sella and cavernous sinus were exposed, the right cavernous ICA was identified with the Doppler and surgical navigation. Although the ICA appeared to be just superior to the intended dural opening, when the straight micro-blade was used to open the cavernous sinus dura, arterial blood came forth under moderate pressure. The bleeding site was repaired with muslin gauze, abdominal fat, collagen sponge, and BioGlue tissue sealant (CryoLife, Inc., Kennesaw, GA). Because of the likelihood of an ICA injury, the procedure was aborted. Her angiogram showed no ICA injury and a follow-up computed tomographic (CT) angiogram 5 days later was normal; she remained neurologically intact and had stereotactic radiotherapy to control her tumor.

DISCUSSION

Summary of Experience

In this series of 631 transsphenoidal procedures, there were three instances (0.48%) of intraoperative ICA injury associated with sellar dural opening, none of which resulted in new neurological deficits, but each of which contributed to an overall suboptimal outcome in these patients. There were no ICA injuries in the last 510 procedures for tumors that were not solely confined to the cavernous sinus. Although this analysis is retrospective, we attribute the subsequent low incidence of ICA injury, at least in part, to routine use of the Doppler probe and micro-hook blades for every transsphenoidal procedure. A growing experience with the procedure and better understanding of the parasellar anatomy were also likely contributory factors. Below, the literature on ICA injury during transsphenoidal surgery is reviewed, as is the relevant parasellar anatomy. Suggestions on how best to avoid an ICA injury and how to manage one should it occur despite avoidance measures are also provided.

ICA Injuries in Transsphenoidal Surgery

There have been numerous case reports and series in the transsphenoidal literature describing an array of vascular injuries and their consequences, including fatal hemorrhage, carotid occlusion, pseudoaneurysm formation, carotid cavernous fistula, subarachnoid hemorrhage, vasospasm, and distal embolism with infarction (2, 20, 24, 26, 27, 34, 35, 37). Such injuries have occurred with all approaches, including sublabial, transseptal, direct endonasal, purely endoscopic, and extended approaches. In larger series, rates of ICA injury have ranged from 0 to 3.8% (1, 3, 5, 6, 9, 16, 18, 26, 27, 33, 37, 43). Surgeons with the largest transsphenoidal experience tend to have the lowest rates of ICA injuries, as shown by Ciric et al. (6) in their survey of 958 neurosurgeons regarding transsphenoidal complications. The overall incidence of ICA injuries was 1.1%, with 12% of respondents reporting that they had experienced an ICA injury. The rate of ICA injury was inversely proportional to the surgeon's transsphenoidal experience, being 1.4% for the least-experienced surgeons (<200 transsphenoidal procedures), 0.6% for those of intermediate experience (200–500 procedures), and 0.4% for the most experienced (>500 procedures). Other large series have also typically reported an ICA injury rate of less than 1%. For example, Laws (27) and Oskouian and Laws (36), with 4067 procedures, reported a 0.8% incidence of vascular injuries. However, this total included basilar and anterior cerebral artery injury, intracranial hemorrhage, vasospasm, and cavernous sinus thrombosis; ICA injury occurred in only 0.6% of procedures, one of which was fatal and one which resulted in stroke. Raymond et al. (37) reported a series of more than 1800 transsphenoidal procedures in which 0.8% of patients had an ICA injury; of those with ICA injuries, there was a 24% morbidity rate and a 14% mortality rate. Mortini et al. (33) recently reported on 1140 consecutive transsphenoidal procedures for adenoma removal with no vascular injuries. In series of the extended transsphenoidal approach for suprasellar and parasellar lesions, the rate of ICA injury has ranged from 0 to 3.8% (9, 11, 13, 21, 22, 25). In all previous reports, excluding our own on the extended transsphenoidal approach (7, 13), use of the Doppler probe before dural opening is not mentioned as part of the surgical routine. However, Kitano and Taneda (25) do report using the Doppler later during tumor resection within the cavernous sinus to confirm the course of the ICA, a technique with which we agree and strongly recommend.

Avoidance of ICA Injuries

In patients with a normal-sized sella, the cavernous carotid arteries are typically separated by 13.9 to 17 mm (15, 19, 38). The medial extent of the ICA and the lateral surface of the pituitary gland are typically separated by only 2 mm (range, 1–7 mm); however, in approximately one-quarter of individuals, the artery extends through the medial cavernous sinus wall and is in direct contact with the gland (39). In individuals with macroadenomas or other sellar masses, the cavernous carotid arteries may be widely splayed and, in some instances, partially or completely encased by tumor. Because of this variability in the course of the cavernous carotid arteries, close attention to preoperative imaging is essential to appreciate the specific anatomic details of each case. Intrasphenoidal bony septations, when present, provide helpful landmarks relative to the course of the cavernous ICAs and should help guide the degree of sellar bone removal. In contrast, the cavernous sinus dura is not always distinguishable from the sellar dura and, in our experience, identifying this transition is a somewhat unreliable marker of where the cavernous ICAs will lie. The inability to recognize this transition from sellar dura to cavernous sinus dura was clearly a factor in the first two ICA injuries described in this report. The third presumed ICA injury occurred despite the use of the Doppler probe and surgical navigation and can likely be attributed to surgical error in misjudging the precise location of the ICA on the basis of the Doppler signal. However, the fact that the angiogram and subsequent CT angiogram showed no obvious vascular injury raises the possibility that the bleeding was secondary to injury of an adjacent capsular ICA branch, a branch of the middle meningeal complex, or inferior hypophyseal artery, as has been reported previously (28, 39). Despite this uncertainty, it was elected to include this patient as sustaining an ICA injury.

In two technical notes with illustrative cases, Yamasaki et al. (41, 42) showed that Doppler ultrasound can be used to localize the cavernous ICAs in transsphenoidal surgery. Our experience with more than 500 cases of consistently using the Doppler probe has convinced us that the risk of ICA injury on dural opening is largely eliminated if time is taken before dural opening to insonate with the Doppler for both cavernous ICAs. This simple, noninvasive method, which adds 2 to 3 minutes at most to the procedure, is also useful in extended approaches for suprasellar, retroclival, or cavernous sinus lesions in which the ICA and other vessels, such as the anterior cerebral and basilar arteries, may be damaged during dural opening. Although computerized surgical navigation is useful for localizing the ICAs, in our experience, the Doppler is more reliable because it gives real-time feedback. Surgical navigation devices are also prone to varying degrees of inaccuracy even for fixed cranial-base landmarks. Although the Doppler probe requires some subjective interpretation of the exact location from which the audible pulse is emanating, we think the added level of certainty and safety provided with this technique is invaluable, particularly if using the direct endonasal approach because of its slightly off-midline trajectory that typically places the contralateral cavernous ICA within the surgical corridor (*Fig. 1*) (4, 8, 40, 43). Thus, care must be taken to ensure that the contralateral dural opening is not too far lateral. We have been impressed with how often the contralateral ICA is more easily localized with the Doppler than the ipsilateral ICA, and our initial two ICA injuries confirm this reality.

Finally, the use of low-profile hook blades for dural opening also likely decreases the risk of ICA and other vascular injuries because the blade angle allows the cutting force to be directed away from the intradural surface and is directed back toward the surgeon instead. Alternatively, angled pistol-gripped dural scissors can be used for this purpose, as has been described by Rhoton (39). Regardless of technique, the lateral dural opening must be performed with the cavernous ICAs in mind but also must be wide enough to provide adequate access for tumor removal, which, ideally, should extend to the edges of the cavernous sinus bilaterally.

Managing an ICA Injury

Fortunately, most ICA injuries during transsphenoidal surgery are relatively small puncture wounds that can be controlled initially with Gelfoam and cottonoids followed by a more definitive repair. For such injuries, a two-layered muslin gauze patch placed over the puncture site, followed by a fat graft or collagen sponge is often sufficient; fibrin glue or BioGlue can be used to reinforce the repair. Some surgeons advocate Teflon mesh and methylmethacrylate as bolstering (16). Care should be taken not to overpack the repair, which can result in carotid occlusion, as occurred in one of our cases. For larger lacerations, direct suture repair of the vessel is generally not feasible, although use of a Sundt-type encircling clip to preserve vessel patency may be possible in some cases (27). If all else fails, the injury site can be trapped with aneurysm clips, sacrificing the vessel. After ICA repair, an urgent cerebral angiogram should be obtained (20, 24, 26, 27, 37). If a pseudoaneurysm or carotid cavernous fistula is present, these can often be repaired by endovascular techniques (2, 12, 20, 26, 37, 43). If the results of the angiogram are normal after an ICA injury, it is recommended to repeat the angiogram or CT angiogram within 3 to 5 days to monitor for a delayed pseudoaneurysm (27). A CT scan should also be obtained to determine whether or not subarachnoid hemorrhage occurred, which can lead to clinically significant vasospasm (27, 31, 37).

CONCLUSIONS

Although uncommon, ICA injuries during transsphenoidal surgery can lead to serious morbidity or death. Routine use of the micro-Doppler probe for cavernous carotid localization before dural opening and use of angled micro-hook blades for lateral dural opening seem to reduce the risk of ICA injury. These two techniques are recommended for all transsphenoidal procedures performed with either the microscope or endoscope, including extended parasellar approaches, to minimize the risk of ICA and other vascular injuries during dural opening.

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COMMENTS

The authors report their experience of the routine use of Doppler probe and micro-hook blades to avoid carotid artery injuries in endonasal transsphenoidal surgery. This article concerns a large patient series operated on by the same surgeon (DK). The first 114 procedures were performed without the use of Doppler probe and micro-hook blades, and the subsequent 517 procedures were performed with these tools. The results from the comparison of the two groups are clearly explained, and the motivations for routine usage of the two devices during endonasal transsphenoidal procedures are solid.

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As methods of avoiding carotid injuries, the authors present their technique using the microvascular Doppler and hook-type blades for completing the dural opening in transsphenoidal surgery. This article is important, although the effective use of the Doppler in this type of surgery has previously been reported. The authors have thoroughly and systematically reviewed a large number of cases, and the recounting of their personal experience with the problem is valuable. The issues of carotid injuries, how to avoid them, and how they should be treated are well described.

Lacking from the article, and reflective of the retrospective nature of the analysis, is an assessment of the incidence of Doppler silence in their series. A limitation of the Doppler in transsphenoidal surgery is the lack of a consistent internal positive control. Although the contralateral carotid can often provide the positive control, when there is no signal encountered bilaterally, the surgeon is faced with the possibility of a false negative Doppler recording, or Doppler failure. As the authors mention, the absence of signal does not always mean that the dura may be safely opened, or that the carotid is not beneath. It would have been helpful to know what percentage of cases they encountered Doppler silence bilaterally.

The authors also omit some appropriate references to the endonasal transseptal approach. They counterpoise endonasal and sublabial approaches, and argue that endonasal approaches preferentially expose the contralateral carotid, placing the vessel at greater risk. The distinction should not be between endonasal and sublabial approaches, but between a direct sphenoidotomy and a transseptal approach (whether endonasal or sublabial). Indeed, the endonasal transseptal approach maintains the anatomic midline in a similar fashion to the sublabial approach. In spite of its surgical advantages, since 2002, we have also moved away from the endonasal transseptal approach. Currently, we employ the direct sphenoidotomy for the overwhelming majority of our non-endoscopic, transsphenoidal approaches. Although this has improved postoperative patient comfort, one should not lose sight of the intraoperative advantages of the endonasal transseptal approach. The omission of this distinction was undoubtedly unintentional; however, the authors would have made a more accurate argument if they had emphasized that the Doppler is more important during a direct sphenoidotomy approach than when a transseptal approach is performed, whether it is endonasal or sublabial.

In spite of their preferential exposure of the contralateral carotid, and prior to changing their technique, the authors' carotid injury rate was within the reported range for sublabial or endonasal transseptal approaches. The authors suggest that their technical changes reduced the incidence of carotid injury; however, this conclusion would have been more convincing if the incidence between the groups had been statistically significant. Perhaps if pituitary adenomas alone were selected for analysis, the differences may have been significant. Nevertheless, we tend to agree that a wide dural opening can be an important factor in a successful operation; the Doppler provides the surgical confidence to achieve this important technical step. In our experience, we have found that the Doppler can be extremely useful in selected cases and think that it should at least be available during every transsphenoidal approach. The hooked blades for opening the dura are a less dramatic but logical innovation for providing safety and efficacy.

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This article discusses the use of a simple technique to prevent carotid artery injury during transsphenoidal surgery. Although the incidence of this complication is small, it is higher with the endonasal approach and when the technique is performed by less experienced surgeons. It may also be higher with the extended transsphenoidal procedures. The technique with a microDoppler is simple, quick, and effective in preventing carotid artery injury when the exact location of the carotid is not evident.

Some authors have proposed the use of image guidance techniques for this as well, thereby precluding the need for flouroscopy to locate the sella. That is very effective in identifying the cavernous sinus and carotid artery if the registration errors are small. Although there have been some articles discussing this technique, this article has a large series and is well presented.

The additional point of using an angled hook-knife blade is well taken. Most of the carotid injuries I have heard about were with the use of an 11-blade with direct penetration. I tend to use the right and left angled pistol grip scissors for opening the dura. It is effective when cutting the dura and for dissecting the dura away from the gland.

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Avoidance of complications in neurosurgery is based on the knowledge of the anatomy and physiology, and the cumulative experience of the surgeon. Technologies that augment knowledge and experience are of certain value, but cannot replace these precepts. In the current report, the authors describe two technologies, Doppler microprobe and a specialized cutting blade, which they employ to reduce the incidence of carotid artery injury during pituitary surgery. I suspect that the reduction in the incidence of injury that they observed owes to experience rather than the technology. The cost effectiveness of any technology must be considered, and it is not clear whether or not the Doppler and micro-hook blade are any more effective in preventing carotid injury than less expensive techniques. I prefer to puncture the dura at the lateral margin of the bony exposure with a 25-guage needle and extend the dural opening laterally after I have identified the wall of the cavernous sinus within the sella. Fortunately, carotid injury is so infrequent that it is unlikely that the most efficacious technique will be determined.

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The injury of the intra-cavernous carotid artery is perhaps the most feared complication of transsphenoidal surgery. The avoidance of this catastrophic complication is considered by every experienced transsphenoidal surgeon, and each surgeon has a series of considerations for its avoidance. These considerations include careful evaluation of the sella dimensions and its contents, specifically the space between the two carotid arteries. In addition, preoperative knowledge of the sphenoid sinus architecture and careful identification of both sphenoid ostia and sphenoid sinus osseous septations are also used. Some centers routinely use frameless neuronavigation. Fortunately, these considerations allow for a very low incidence of carotid artery injury in most busy transsphenoidal centers with experienced surgeons. The authors describe their experience with the use of a micro-Doppler probe to localize the position of the carotid arteries before the dura over the sellar is initially opened and the subsequent use of hooked micro blades to minimize the inadvertent perforation of the carotid artery during the completion of the durotomy. The use of Doppler probes in neurosurgery is well described and routine in most centers that perform cerebrovascular surgery and transcranial surgery for brain tumors that may involve the vasculature of the brain. The technique described in this article is certainly very reasonable.

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