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REVIEW Open Access

Inadvertent internal carotid artery (ICA) injury during transsphenoidal surgery: review of literature

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Abstract

Background: Internal carotid artery (ICA) injury is a hazardous catastrophe for the skull base surgery team. We aimed to illustrate the vital joints in this hazardous event during endoscopic surgery.

Main text: The condition is rare (1.1%) but fatal per se. Working in the field of endoscopic surgery is not free of charges. It demands a thorough knowledge of anatomy, variations, and pathoanatomy to expect what can be seen thereafter. Once the injury occurs, one must have a quite clear plan to proceed. Marvelous bleeding is confusing not only in the field but also in the mind process.

Conclusion: Endoscope teams when expose to this event should think in a stepwise manner. In our review, we explained the pathoanatomy of the field after an injury, pre-conditions of injury, and how to avoid certain drawbacks during management.

Keywords: ICA, Pituitary surgery, Intraoperative injury, Skull base surgery

Background

Carotid artery injury (CAI) is regarded as a nightmare for every skull base surgeon during his carrier [1, 2]. This derangement can change the roadmap of a successful surgery into a catastrophe. Endoscopic skull base surgery has been evolved over the last decades and recruited many candidates to its field [3, 4]. However, it requires a long learning curve and a strong anatomical base. The anatomical knowledge in endoscopic skull base surgery is not confined to typical parameters and fixed points. In contrast, strong skull base knowledge is embedded in the exact identification of variations, anomalies and pathoanatomical changes that exerted by the diverse pathologies [5]. These "obstacles" were prophylactically prohibited by advanced neuroimaging modalities.

Although, carotid artery injury is still possible whatever the complexity of lesion and the experience of the surgeon [6]. The insult of the carotid artery (as any other hemorrhage) is immediate, unlike cerebrospinal fluid (CSF) leakage which can be delayed and under low pressure. Other insults that can happen to the carotid artery are vessel spasm, thrombosis, pseudoaneurysm formation, and finally carotid-cavernous fistula [7, 8].

The incidence of carotid artery injury in transsphenoidal surgery is 1.1% [1, 2, 6]. It has been recorded previously in different situations like sinus surgery [9] and during treatment of giant cell tumors of clival regions [10]. It is higher in extended lesions like chordomas and expanded endonasal endoscopic surgeries and reach up to 9% [2].

In the works of literature, no standard protocols have existed for management [6–8, 11–13]. We shall represent our review of the current management ideas previously reported.

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Main text

Systematic reviews

During the past 5 years, two systematic reviews discussing the reported incidence of ICA injury in endoscopic endonasal surgery were conducted. The first one was held by Chin and colleague (2016) [8]. They reviewed 25 articles with 50 cases in different endoscopic purposes and not exclusively discussing pituitary surgery. They found that the most commonly injured ICA segment was the cavernous (34 cases), followed by the ophthalmic (three cases). Injuries occurred more commonly on the left than right and throughout all steps of expanded endonasal sphenoidal surgery (EESS). The second review was conducted by Perry and colleagues (2019) [14]. They estimated the incidence of ICA injury in different approaches of transsphenoidal pituitary surgery (microscopic versus endoscopic) exclusively. They reported 35 cases/11149 patients (5/2672 (0.2%) versus 30/8477 (0.4%)) for microscopic and endoscopic transsphenoidal surgery respectively.

Preoperative measures

Skull base surgery has long-run evolution from the first elementary steps of sinus surgery up to extended skull base surgery [13]. The whole skeleton of endoscopic surgery is made up of anatomy [5]. Solid knowledge is a good shield against carotid artery injury. Kassam and coworkers developed a special classification system to minimize neurovascular complications and enhance anatomical knowledge [15]. Prophylactic identification of injury susceptibility always wins. Valentine and Wormald published their article that identified the risk factors for carotid artery injury and failure to obtain visualization of carotid was one of these factors [16]. In 2016, Valentine and co-workers reproduced the scenario of carotid injury in sheep and they applied effective training strategies to control bleeding [17].

Anatomy factor

The relationship between the artery and sphenoid sinus is not anatomically fixed [5]. The internal carotid artery (ICA) is shielded with a very thin layer of bone (0.5 mm) thick and is not sufficient to protect the artery from trivial manipulation around it [18]. It has been found that up to 4% of cases, the internal carotid artery is separated from sinus but a mucosal membrane and dura [18]. Fernandez-Miranda and colleagues studied the anatomic relationships of sphenoid septa and ICA anatomically, they found that most (87%) of the intrasphenoidal septations insert at the carotid artery in the parasellar or paraclival segments [19]. When more than one septation is present, at least one of them will insert into the carotid prominence [20, 21]. Previous studies, however, have shown varying results. Abdullah et al. [22] examined by computed tomography (CT) with 5-mm slice thickness of 70 studies, however, have shown varying results. Abdullah et al. found that in only 22 of 70 subjects (31%), the septa were related to the internal carotid artery. Unal and colleagues studied the anatomic variations in the sphenoidal septa were related to the internal carotid artery [23]. They studied the anatomic variations in the sphenoid sinus of 56 subjects through 3-mm slice thickness CTs and showed that in 34 of 112 sides (30.3%), a septum protruded the ICA. However, in Fernandez-Miranda et al. study, the CT slice thickness was only 1 mm. Rhoton examined sphenoidal septa and found they are terminating into the carotid artery in 40% of specimens [24]. He also examined 50 adult sphenoid sinuses and recorded about 30% incidence of septa inserting into the carotid prominence.

However, all approaches in transsphenoidal surgery are directed to the midline. The distance between the two arteries is ranging from 8 to 10 mm. So, tracking the midline is not always a working step; for example, multiple septations of the sphenoid sinus may include septal walls inserted into the ICA bony canal [25]. Cavernous ICA anomalies are rare in the general population [26] and merely recorded in patients with pituitary pathology. Few reports on concurrent association with cavernous ICA aneurysms which result in ICA rupture [27–29].

Patient factor

Several factors were associated with cavernous ICA injury. These factors included revision surgery, radiotherapy, large clival mass, acromegalic features, and bromocriptine therapy for a long time [4, 8, 9].

Tumor factor

High-definition, multi-slice CT scan of paranasal sinuses should be available to the pituitary surgery team before the induction of general anesthesia [13]. Computed tomography is important to delineate the bony skeleton of the surgical corridor while magnetic resonance (MR) angiography shows the vascular tree around the pituitary tumors. Recent studies recommended the utilization of intraoperative neuro-navigation to avoid vascular injury [6, 30].

Tumors come in contact with ICA are mainly encasing tumors other than destructive in nature. This encasement weakens the artery wall from without and makes it susceptible to bleed and vasospasm [31]. Vasospasm can result from tumor dissection over a vessel or cavernous sinus hemostasis by inserting multiple layers of surgifoam [16].

Intraoperative measures

The ICA injury harbor high pressure and flow stream of blood that can disturb the scene immediately. It is important to control the field immediately to apply a quiet environment able to set strategies to deal with this catastrophe [32].

Surgical field control

From the literature review, certain points are important to be achieved. These points are the following:

- Blunt instruments like a blunt suction tube, curettes, and dissectors are advocated by the authors [33].
- Bone chips should be removed better by serial cutting with low profile Kerrison other than twisting and grasping. Besides, using diamond burrs are preferred than cutting burrs [34].
- The endoscopic surgery team is usually composed of neurosurgeons and ENT specialists. Usually, the operative steps before durotomy are held by ENT (ear, nose, and throat) surgeons. At the event, two surgeons should be involved. One should direct the bloodstream away from the camera while the other tries to get visualization to achieve hemostasis [2].
- Large bore suction tubes (two 8–10F) should be introduced in the field. The suction tubes should be applied at the inferior angle of the field to direct blood away from the endoscope [2, 10].
- A pedicled septal flap should be prepared at once and applied gently to the nasopharynx [35].
- The second surgeon must put the suction tip to the puncture site [1].

Hemostasis

Many methods were tried to save the catastrophic situation and ICA ligation was one of them. Carotid artery ligation is not a wise decision as to its principle [7, 36, 37]. Generally, in endoscopic pituitary surgery, the dominance of ICA is not in question. Hence, ligation can lead to remarkable stroke and death. Besides, endovascular treatment will be omitted as an option. The mainstay of treatment is nasal packing [4, 7, 33]. Nasal packing is not advocated if the dura is opened if so, shift to other strategies [1].

Sphenoid ostium should be widened sufficiently to nasal packing. Carotid artery compression is advocated ipsilaterally. Weidenbecher and coworkers advised compressing both carotids [38]. Head elevation and controlled hypotension are not scientific strategies to stop bleeding [6, 7]. In contrast, normotensive is advised to preserve cerebral perfusion pressure. There are many options for nasal packing in the market, gauze still the easiest, most available, and sufficient to do the required compression [16]. On the contrary, nasal packing has its own complications. Overpacking and infection are the main complications of nasal packing [39]. Overpacking exerts enormous pressure on the carotid artery that leads to ischemia thereafter [34, 39].

Muscle patch

Muscle patch achieved hemostasis in animal models of ICA injury [34, 39]. Muscle patch contains specific materials that enhance hemostasis better than cellulose and thrombin-gelatin matrix [3, 8]. A pseudoaneurysm can be developed even in the presence of a muscle patch. Muscle patch is prepared from quadriceps, fascia lata, and sternocleidomastoid muscle. The muscle patch is harvested and crushed by metal surfaces to maintain its delicate or sheet-like appearance [39]. The graft is then introduced by using Blakesley forceps with tight adherence to the injury site [1]. The graft needs 10–15 min to maintain hemostasis. Septal flap might be applied then over the muscle graft when the carotid artery needed to be dissected thereafter. Fibrin glue might also be used over the muscle patch [16, 38].

Closure of injured vessel

There is a delicate line between having good hemostasis by closing the defect and achieving no stenosis [32]. Laws and colleagues described a method of carotid artery repair by suturing [40, 41]. Other experimental studies reformed a special clip for ICA injury. A specialized U-clip device to close the rupture site by using vascular clamp [16, 34, 40, 42]. This method was found to be very effective when exposure around the artery is sufficient. Unfortunately, this type of clips is no longer available from the manufacturers.

Aneurysm clip (T2) was capable of achieving hemostasis in all injury types as studied by Padhye and co-workers [34].

Bipolar electrocauterization is not an effective model of treatment even in animal studies. Cauterization produced a coagulum at the site of injury; this coagulum makes the wall vulnerable to further bleeding, enlarging the defect and stenosis [34].

Endovascular treatment

Vessel occlusion and decreased arterial flow are both can be achieved by endovascular treatment [2]. In many scenarios, the endoscopic achievement of hemostasis is before transfer to an angiography suite. Endovascular occlusion of the vessel is done usually by coil or balloon [43]. Either method used, the coil should be deployed at the site of injury to prevent extravasation of blood through a defect in an anterograde or retrograde direction [27]. Therefore, care should be paid to avoid ophthalmic artery occlusion. If time permits, collateral circulation should be studied well as well as the feasibility to occlude the offending vessel (Wada test) [7, 44]. The stent graft is now performed by many interventionists. This technique is a challenging process but still effective in achieving vessel patency. Spasm of ICA, distant migration, and stenosis are possible complications [27, 43]. Sylvester and colleagues [43] suggested an algorithm for treatment of ICA injury by implementation of several endovascular methods, and high flow external carotid-to-internal carotid (EC-IC) bypass was the final choice when all methods failed.

Postoperative measures

Pseudoaneurysm and carotid-cavernous fistula are both hazardous and late complications to ICA injury [45]. Pseudoaneurysms are as high as 60% after ICA injury; there is a risk of rupture for up to 3 months [7]. Angiographic repair by grafting of occluding is the most powerful preventive measure ever estimated. Similarly, carotid-cavernous fistula can be treated in the same way as well [7].

Conclusion

Endoscope teams when expose to this event should think in a stepwise manner. In our review, we explained the pathoanatomy of the field after an injury, preconditions of injury, and how to avoid certain drawbacks during management.

Abbreviations

CAI: Carotid artery injury; CSF: Cerebrospinal fluid; CT: Computed tomography; EC-IC: External carotid-Internal carotid; ENT: Ear, nose, and throat specialty; EESS: Expanded endonasal sphenoidal surgery; ICA: Internal carotid artery; MR: Magnetic resonance

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Competing interests

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