Classification of Internal Carotid Artery Injuries During Endoscopic Endonasal Approaches to the Skull Base

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Background

Endoscopic endonasal approaches (EEAs) to skull-base lesions have been substantially advanced over the past three decades.[11,24,37] This advancement came from improvements in instruments, surgical techniques, surgical skills, as well as the use of intraoperative imaging.[27,33,37,40] Such advancements have expanded the use of extended EEA for all ventral skull base lesions from the crista galli to the odontoid process. These approaches are gradually replacing some traditional transcranial approaches as well as microscopic trans-sphenoidal surgery, as they are generally considered safe approaches.[27] The challenge with these approaches is related to the narrow corridors and complex neurovascular anatomy of the surrounding structures where major vessels run within tight boney canals and are crossed by cranial nerves, which makes it very difficult to control or repair if they are injured.[10,13,15,23,24,26]

Internal carotid artery (ICA) injuries are rare but can be catastrophic when they occur during EEAs.[1,4] The reported incidence of ICA injury during EEA to the skull base ranges from 0.2–1.4% compared to 3–8% in standard open skull base approaches.[6,7,11,12,45]

Unfortunately, the literature lacks a surgical anatomical classification for these injuries, and most publications only reported the mode of injury without detailed anatomical description of the injury.[6,7,11,16,26] Developing a classification based on the pattern of injury and the functional outcome will lead to better advancement in management, as it represents the first step toward creating guidelines for the prevention and perioperative management of these injuries. This study proposes a classification of ICA injuries during EEAs to the ventral skull base.

Methods

A literature review of the MEDLINE database using the PubMed search engine was performed. All published cases of ICA injury during EEAs in the literature between January 1990 and January 2020 were thoroughly reviewed. Animal studies, simulation studies, and non-English studies were excluded from the study.

Three main factors were used to defined the three main types, first is the type of vessel injured (parent artery vs. a branch of the ICA); when the injury involves only a branch of the ICA the type of injury was named “branch injury” and it is classified as Type I. The second and third factors (apply to parent vessel injuries) are the cause and degree of the injury (sharp penetrated injury vs. laceration injury); when the injury involves a sharp penetration the type of injury is named “penetration injury” and is classified as Type II and when the injury is a tear in the three layer of the ICA wall it is named “laceration” and is classified as Type III.

Further factors were used to divide each type into two sub-types. For the “branch injury” (Type I); the distance of the stump from the ICA is an important factor, thus we divided this type further into branch injury with stump more than 3 mm or <3 mm, this is based on the fact that stumps of <3 mm are difficult to control with bipolar coagulation without further injury to or stenosis of the parent vessel; which is the main author observation. The second type (Type II) is a sharp penetration injury, which is further divided based on number of ICA walls involved; into single wall penetration or two-sided wall penetration “through and through” injury. The third type (Type III) was divided into two subtypes, partial laceration (including branch avulsion) or completes transection of the ICA wall with or without fulguration (burning contusion) of the wall of ICA [Table 1].

Table 1: Internal carotid artery injuries during endoscopic endonasal approaches.

Branch injury	Type I	I-A	Stump >3 mm
		I-B	Stump <3 mm
Parent Vessel Injury	Type II	II-A	One wall injury
		II-B	Two wall injuries
	Type III	III-A	Partial
		III-B	Complete transection or fulguration injury

Results

The new classification

ICA injuries during EEAs were classified into three main types and six subtypes [Table 1 and Figures 1-4]. The first type is defined as injury to one of the ICA branches. It can take place during dissection of the petrous or parapharyngeal segments of the ICA, or more distal segments. This type can be further sub-classified based on the distance of the injury to the branch from the parent vessel: branch injury with stump more than 3 mm and branch injury with stump <3 mm [Figure 2]. The second type is the penetration type, where direct sharp penetration of the ICA created by a sharp instrument. This type can be further sub-classified into: injury to the ventral wall of the ICA (one sided), the second subtype is when two walls of the ICA are involved [Figure 3]. The third type is laceration injury, and it can be sub-classified as partial laceration that can be direct tearing of the parent artery or branch avulsion, the second subtype is either transection of the ICA, included in this class is burns (fulguration injury) of the ICA, where there is circumferential injury to the artery with critical stenosis. In type III injuries, all walls of the ICA are involved [Figure 4].

The outcome of the injury based on the proposed classification

The review of the literature revealed 31 papers that reported ICA injuries during EEAs to the ventral skull base. A total of 68 patients were reported in the literature with ICA injuries during EEAs. Type III injury was the most commonly reported in 27 patients and was associated with unfavorable outcomes. In the outcome of these injuries, a total of four patients died and five patients were reported to have neurological deficit, three of them were temporary deficits [Table 2], However, many articles reported a good outcome even with severe injuries. In [Table 2] we outlines the indications for EEAs, ICA segment/methods of injury, classifications, angiographic results, and patient outcomes of all reported cases in the literature.

The “enough distance” of the stump is defined around 3 mm as most bipolar tip is around 2 mm, where the stump can be held by the bipolar tip and coagulated relatively safely, however, when the stump is <3 mm the comfort zone of controlling the bleed using bipolar coagulation is narrowed and might need different technique other than coagulation (e.g., aneurysmal clip) or other management such as endovascular intervention (flow diverters) after temporarily backing.

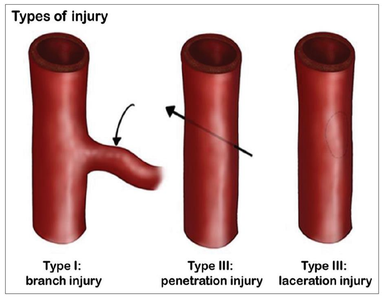

Figure 1: Classification of internal carotid artery injury during endoscopic endonasal approaches. Three main types.

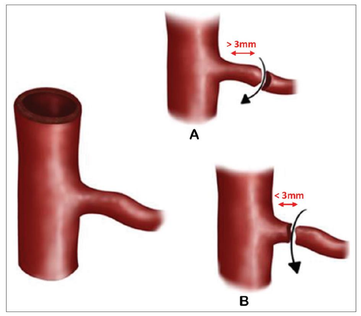

Figure 2: Branch injury of the internal carotid artery (Type I). (A) Distal injury located more than 3 mm from the parent vessel. (B) Proximal injury located <3 mm from the parent vessel.

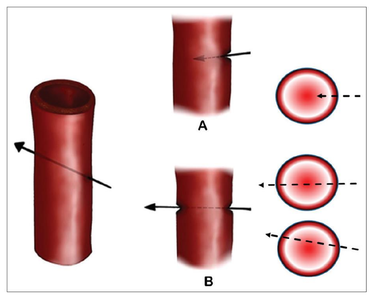

Figure 3: Penetration injuries to the internal carotid artery (ICA). (A) Injury to single wall of the ICA. (B) Two-wall injuries through and through injury puncturing the ICA at two walls (ventral and dorsal), or ventral and side wall.

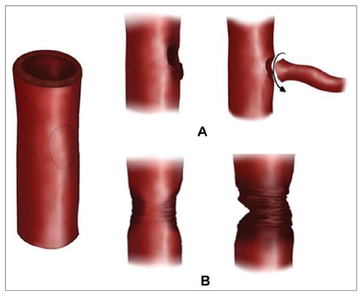

Figure 4: Laceration injuries of the internal carotid artery (ICA). (A) True laceration typically caused by punch/pituitary instruments or branch avulsion-off the wall of- ICA. (B) Complete laceration that includes transection and fulguration (burn/contusion typically caused by aggressive coagulation of the ICA).

Conclusion

This is a novel classification system for ICA injuries during extended endonasal endoscopic approaches. This classification system defines the patterns of injuries and the relationship between the injury and the complication’s mortality and functional neurological outcome. Although it is still need to be validated, we strongly believe. It will lead to better recognition of the ICA injuries during EEAs, which will be the first step toward creating protocols for perioperative management of these injuries.

Translational Potential

This proposed classification will help in unifying the description of such kind of devastating complication between the other specialties involved in managing this complication including; neurosurgeon, rhinologists, neurointensivists, neurointerventionists. It will have a major contribution in facilitating the management among these specialties to provide an optimal patient care.