Carotid Artery Injury in Sphenoid Surgery

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outlines

- Sphenoid Sinus Development and Surgical Anatomy
- Epidemiology and Risk Of Injury
- Intra-op Management of Ruptured ICA
  - Controlling the Surgical Field
  - Intra-op Hemostatic Technique
- Endovascular Intervention
- Delayed ICA Injury
- Complications
- Outcome

Sphenoid Sinus Development

- Sphenoid: in month 3, mucosa invaginates into posterior cartilaginous septum;
- wall ossifies and the intervening cartilage resorbs in the 2nd and 3rd yrs
- Pneumatization
  - Between birth and 3 years of age
  - 3 - 7 yrs
  - 7 – 12 yrs

Sphenoid Sinus Development

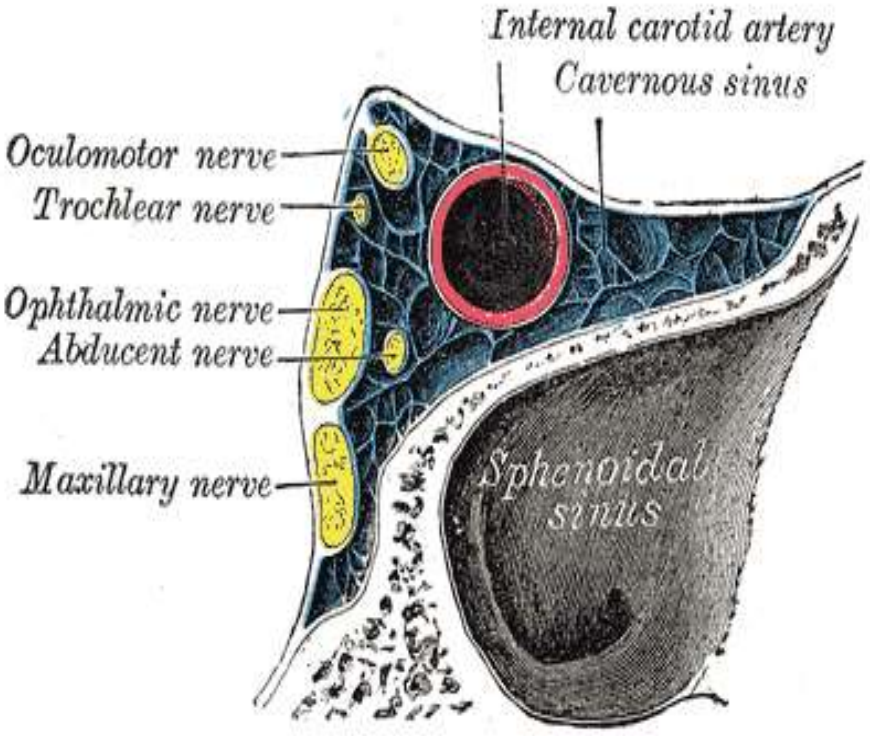
- Asymmetrical devolopnment, separated by the intersinus bony septum → goes off the midline →insertion in the lateral wall of the sphenoid
- When removing the septum in these cases, as a brisk avulsion may result in carotid rupture or optic N. injury

Sphenoid Sinus Anatomy

- Drains into the sphenoethmoid recess
- The ostium is classically situated
  - 7 cm from the base of the columella
  - at an angle of 30°
- Endoscopically, the posteroinferior end of the superior turbinate points superiorly and medially toward the ostium and thus represents a very important landmark to identify it (83% medial to it and 17% lateral to it).
- When polypoid changes are present distorted anatomy, the ostium can be located adjacent to the nasal septum, at the level of the posterior orbital floor seen through the middle meatal sinusotomy, usually within 10–12 mm from the superior arch of the choana, and approximately 7 cm from the columella

Sphenoid Sinus Anatomy

- Cavernous sinus is just lateral, including the ICA and CN III-VI
- ICA produces a prominence in the lateral sphenoid sinus wall in **65%** of individuals; approximately **25%** are partially dehiscent.
- An optic nerve prominence is present in **40%** of individuals with dehiscence in **6%**



Sphenoid Sinus Anatomy

- 3 degrees of pneumatization:
  - Sellar (86%)
  - Presellar (11%)
  - Concha (3%)
- Pneumatization of the sphenoid
  - Above and below the optic canal
  - Between foramen rotundum and the pterygoid canal

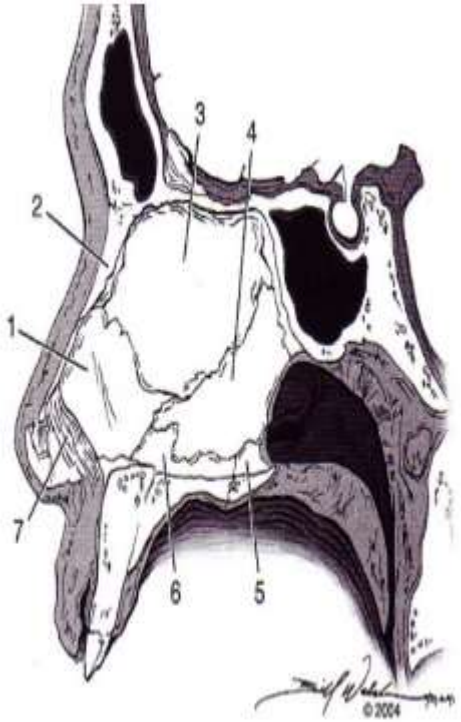


Figure 22.3 Nasal septum. 1, quadrangular cartilage; 2, nasal bone; 3, perpendicular plate of ethmoid bone; 4, vomer; 5, nasal crest of palatine bone; 6, nasal crest of maxilla; 7, membranous septum. (Illustration by William E. Walsh, MD, CMI ©2004.)

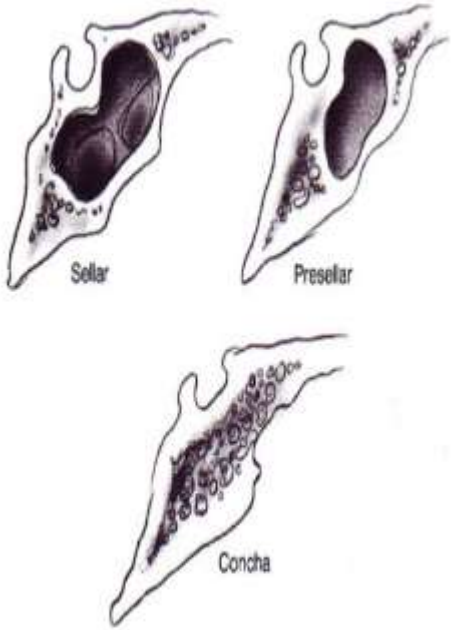


Figure 26.5 The Hamberger classification of sphenoidal pneumatization.

Introduction

- Over past 2 decades, Endoscopic approach gain popularity
- One of the most feared complication is Carotid Artery Rupture Of ESS and S.B Procedure
- Injury to Cavernous ICA could Results in
  - Rupture/Hemorrhage
  - Spasm
  - Thrombosis/ Embolus
  - Caritococavernous Fistula
  - Death

Epidemiology

- Very Rare
- May et. al had 1 case among 4691 ESS patients
- 28 cases in all English literature in ESS Cases
- Raymond et. al and Ciric et. al found an incidence of 1.1% of ICA injury after the microscopic Trans-sphenoid Hyposphesectomy.
- Gardner et.al, and couldwell et.al, reviewed the Extended Endoscopic Approach for resection of Crainopharyngoma, Chordoma and chondrosarcoma and found 5-9% ICA Rupture

Risk Factors

- Prevention Better Than Treatment
- The anatomic Relation between ICA and Sphenoid
  - Fujii et. al
    - The bony Wall is not sufficient if < 0.5 mm thick.
    - Lateral Sphenoid wall Dehiscent in 4 – 22% of Patients.
  - Rhen and Roton, ICA Bulge in sphenoid in 71% and ICA may be located 4 mm from midline
  - While others found that the distance between 2 ICA is 4 mm in 16.3%

Risk Factors

- Cavernous Sinus Anomalies
  - ICA Aneurysm represents12.8 % of all intracranial aneurysms
    - Incidence increase with pituitary adenoma.
    - Risk of rupture if unrecognized, uncontrolled hemorrhage and subsequent death
- Numerous other risk factors linked to ICA Rupture as indicated by Raymond et. al and the review of 111 cases
  - 1- Revision Surgery
  - 2- Radiotherapy
  - 3- Bromocrptin therapy
  - 4- Acromegaly (more tortious and ectatic ICA)
  - Either because fibrosis and adherence of the tumor to ICA or simply because more aggressive attempts to resect lesion

Risk Factors

- Tumors Closely adherent to ICA needs carful dissection
  - Bejjani et. al found that Vasospasm occurred in 9/470 patients undergone S.B tumor dissection and 3 of them had permanent defect
  - Vasospasm is manifested by altered level of consciousness and hemiparesis
  - Risk factors for vasospasm are pre-op embolization, tumor size, vessel encasement or narrowing and total operative time.
  - Law also cautions about displacement of ICA during dissection were 1 had fatal and 2 had none fatal ICA spasm and thrombosis post-op

Risk Factors

- It is imperative to identify patients with risk factors to avoid complications
- CT could delineate the Blood vessel anatomy and its relation to sphenoid
- While MRI demonstrate aneurysm which if suspected should be confirmed with MRA

Box 1
Risk factors for ICA rupture

- Anatomic relationships
  - Carotid dehiscence
  - Sphenoid septal attachment to ICA
  - Midline ICA
- Revision surgery
- Prior radiotherapy
- Prior bromocriptine treatment
- Acromegaly

Carotid Artery Ruptured !!!
What is your next Step ?!!!!

Carotid Artery Ruptured !!! What is your next Step ?!!!!

Intraoperative Management of Cavernous ICA Rupture

- Very Challenging , high pressure, high flow bleeding
- Internal carotid arteries flow rate 132–367 mL/min (mean, 265 mL/min ± 60)
- Loss of orientation and obscure visual feild
- The surgeon should have a plan for each possible complication
- Formulating and executing a plan of action during crisis is difficult

Intraoperative Management of Cavernous ICA Rupture (controlling the Surgical Field)

- Valentine et. al. developed a reproducible ICA Catastrophe
- He described 42 ICA injury in this model and steps to control the field and the bleeding as follow
  - 1- 2 surgeons skull base technique will give more dynamic scope handling
  - 2- Navigate the scope tip away from the vascular field to maintain vision
  - 3- Place the endoscope on the contralateral side of the bleeding ICA
  - 4- Use 2 large bore suctions on the ipsilateral bleeding ICA

- Two surgeons are engaged, allowing one surgeon to control the bloodstream, directing it away from the endoscope while the other obtains visualization to attempt hemostasis
- Two large-bore (10F) suction devices and, if available, a lens cleaning system for the endoscope should be used.

- The second surgeon uses suction downside the nose with predominant bleeding to direct flow away from the other side.
- The primary surgeon places the endoscope down the contralateral side, using the posterior septal edge as a shield from the blood flow.
- The primary surgeon clears blood ahead of the endoscope using the second suction device. A pedicled septal flap should also be cleared and pushed into the nasopharynx.
- The second surgeon is then free to “hover” the suction device directly over the site of injury to help gain visualization for the primary surgeon.

Fig. 2. Endoscope placed within the left nostril is protected from frequent tip soiling by . Animal model of endonasal carotid artery injury, with exposure of the carotid artery within sphenoid sinus.

Intraoperative Management of Cavernous ICA Rupture (Intraoperative Hemostatic Technique)

- Emergency ligation of ICA
  - Traditional
  - Complications; stroke or even death
  - Ineffective (collateral and compensation)
- Ligation of Int. and External CA will waste the time and block the access for interventional Radiologist

Intraoperative Management of Cavernous ICA Rupture (Intraoperative Hemostatic Technique)

- In case of massive bleeding**, Immediate packing is needed**
- Head Elevation and controlled hypotension is unnecessary
  - Massive Bleeding → Hypotension
  - The urgent need for control by anesthesia
- Large bore suction (in addition the hypotension)
- Ipsilateral Common Carotid Artery Compression

Intraoperative Management of Cavernous ICA Rupture (Intraoperative Hemostatic Technique)

- Kassam et. al., solares et. al and pepper et.al
  - Maintain Normotensive condition through resuscitation and fluid replacement to maintain cerebral perfusion
  - However, this is difficult during acute bleeding
  - After control bleeding, BP should be maintained to achieve adequate cerebral perfusion

Intraoperative Management of Cavernous ICA Rupture (Intraoperative Hemostatic Technique)

- Different Packing agents are available
  - Gauze
  - Teflon and methyl methacrylate patch
  - Syvek Marine Polymer
  - Fibrin Glue
  - Oxidized Cellulose
  - Thrombin Gelatin Matrix
  - Oxygel and Glue

Intraoperative Management of Cavernous ICA Rupture (Intraoperative Hemostatic Technique)

Table 1
Classification of topical hemostatic agents and sealants.

Categories	Product	Origin	Active ingredients
Adhesive hemostats	EVICEL	Human	Human fibrinogen + human thrombin
	Tissucol	Human/animal	Human fibrinogen + human thrombin
	Beriplast	Human/animal	Human fibrinogen + human thrombin
	TachoSil	Human/animal	Equine collagen + fibrinogen and thrombin
Topical hemostats	Surgicel	Vegetable	Oxidized regenerated cellulose
	FloSeal	Animal	Bovine collagen + bovine thrombin
	Spongostan	Animal	Porcine gelatin
	Surgiflo	Animal/Human	Porcine gelatine + human thrombin
Adhesives	Omnex	Synthetic	Cyanoacrylate
	Bioglue	Semisynthetic	Bovine albumin glutaraldeide
	Coseal	Synthetic	Polyethylene glycol
	Glubran	Synthetic	Cyanoacrylate

Intraoperative Management of Cavernous ICA Rupture (Intraoperative Hemostatic Technique)

- Pack application
  - Stop the bleeder But not to obstruct the vascular lumen
  - Contraindicated if the dura is opened as blood is likely to track back into the subdural space
  - Absorbable Vs. None absorbable
- Raymond et. al
  - Success controlling bleeding in 14 patients with Oxidized Cellulose, Muscle plug and tissue adhesives
    - 9 patients needed no further intervention (F/U 6 months to 10 years)
    - Recurs in 3 patients and need further management (Endovascular Stent/Occlusion)
    - 1 Died at day 7 (Concurrent Basilar A Compression)
    - Another died 2 months later (Tumor Recurrence)

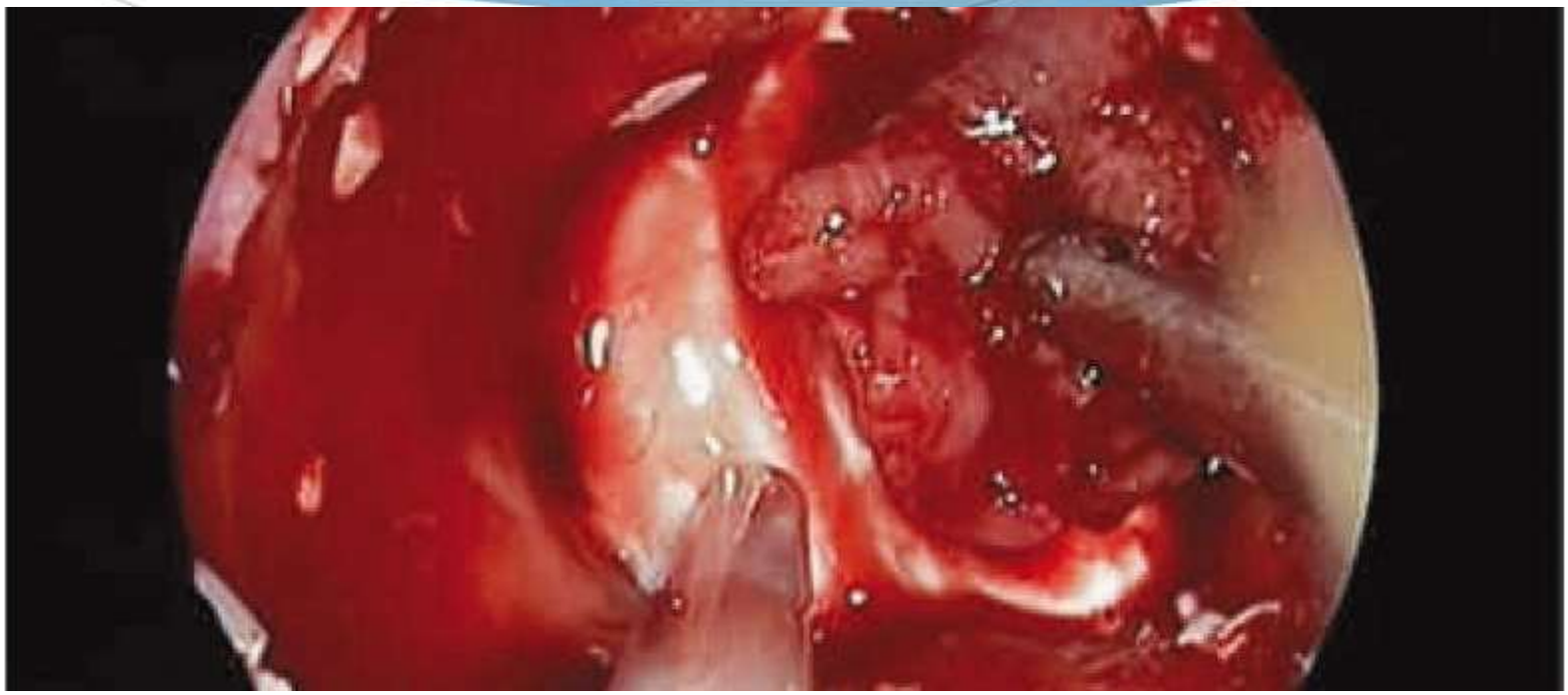
Intraoperative Management of Cavernous ICA Rupture (Intraoperative Hemostatic Technique)

- Valentine et. al compared different hemostatic Agents in ICA injury
  - Thrombin Gelatin Matrix, Oxidized Cellulose and Crushed Muscle patch
  - Avoid ICA Compression
  - Hemostasis was not achieved in all agents
  - However, Crushed Muscle Patch achieved hemostasis in all and was superior to others
  - Mean time 11 min. and 25 sec.

Intraoperative Management of Cavernous ICA Rupture (Intraoperative Hemostatic Technique)

- Muscle is harvested from the thigh (usually prepared for fascia lata graft in skull base cases) or sternocleidomastoid in the neck
- A 2 X 1.5 X 1 cm graft is harvested then crushed between two metal kidney basins and, after gaining control of the surgical field, it is placed directly over the injury site with Blakesley forceps
- Need to be held in contact with injured vessel for 12 min
- If the carotid is likely to be exposed to the nasal cavity, the muscle patch should be reinforced with an overlying septal flap

Fig. 3. 'Crushed' muscle patch in situ on carotid injury site. Complete hemostasis has been achieved.



Placement of Muscle patch pack over an Injured ICA

- As Proposed by Padhye1 et. al
  - If the immediate postoperative angiogram is normal → ICU monitoring for 1 week
  - Rmove the pack and repeat angiogram
  - If this is again normal, then the angiogram is repeated at 6 weeks, 3 months, and 1 year.

Intraoperative Management of Cavernous ICA Rupture (Intraoperative Hemostatic Technique)

- Over packing could lead to undesirable outcome
- Raymond et. al, packing is involved in the mortality and morbidity of patients
  - Review of angiographic results of their patients (12)
  - 8/12 developed ICA Occlusion
  - 4/12 developed ICA Stenosis
- Law, proposed that while maintain the patency of B.V preferred, in some circumstances packing to occlude ICA is the only option with increasing BP Hoping that collaterals will prevent stroke

- If adequate exposure of the vasculature and injury site is not enclosed by bone or difficult to access, direct closure of the injury is possible
- Valentine et. al, described the use of U-clips anastomotic Device (Medtronic, Jacksonville, FL,USA)
  - As used in CABAG anastomosis and Dural Reconstruction of Skull Base
  - Was Very effective achieving hemostasis and maintaining the patency of ICA
  - No long term F/U
- Bipolar electrocauterization was not recommend (Padhye et al)
  - B/C of delayed secondary hemorrhage as well as total carotid occlusion, worsening of the injury, enlargement of the defect

Fig. 4. Four endoscopically place U-clips close the ICA injury site. Hemostasis has been achieved while maintaining vascular patency, and without significant narrowing.

Intraoperative Management of Cavernous ICA Rupture (Intraoperative Hemostatic Technique)

- If intraoperative measures failed,
  - Angiography (endovascular intervention) while patient is intubated
  - Even if hemostasis is secured, All patients need angiogram to detect adequacy of packing, patency of the lumen and/or complication
  - The surgeon should be around in order to loosen the pack if the defect could not be detected

Intraoperative Management of Cavernous ICA Rupture (Intraoperative Hemostatic Technique)

- The optimal angiographic test is BTO
- However, this requires an awake patient for full neurologic exam.
- This is unwise in face of active bleeding and HD instability
- There are some other measures to detect adequacy of collaterals
  - 1- Analysis of pre-op MRI
  - 2- Transcrainial Doppler analysis
  - 3- SPECT Imaging
  - 4- Xenon CT
- Note that well performed BTO carries Risk of 5-10% of Delayed infarction after therapeutic Carotid A. occlusion

Intraoperative Management of Cavernous ICA Rupture (Intraoperative Hemostatic Technique)

- Endovascular technique available for interventional radiologist are
  - 1- Balloon Embolization
  - 2- Coil Embolization
  - 3- Endovascular stent graft Placement (ESGP)
- If both BTO and ESGP failed → Surgical Bypass procedure

Endovascular Techniques

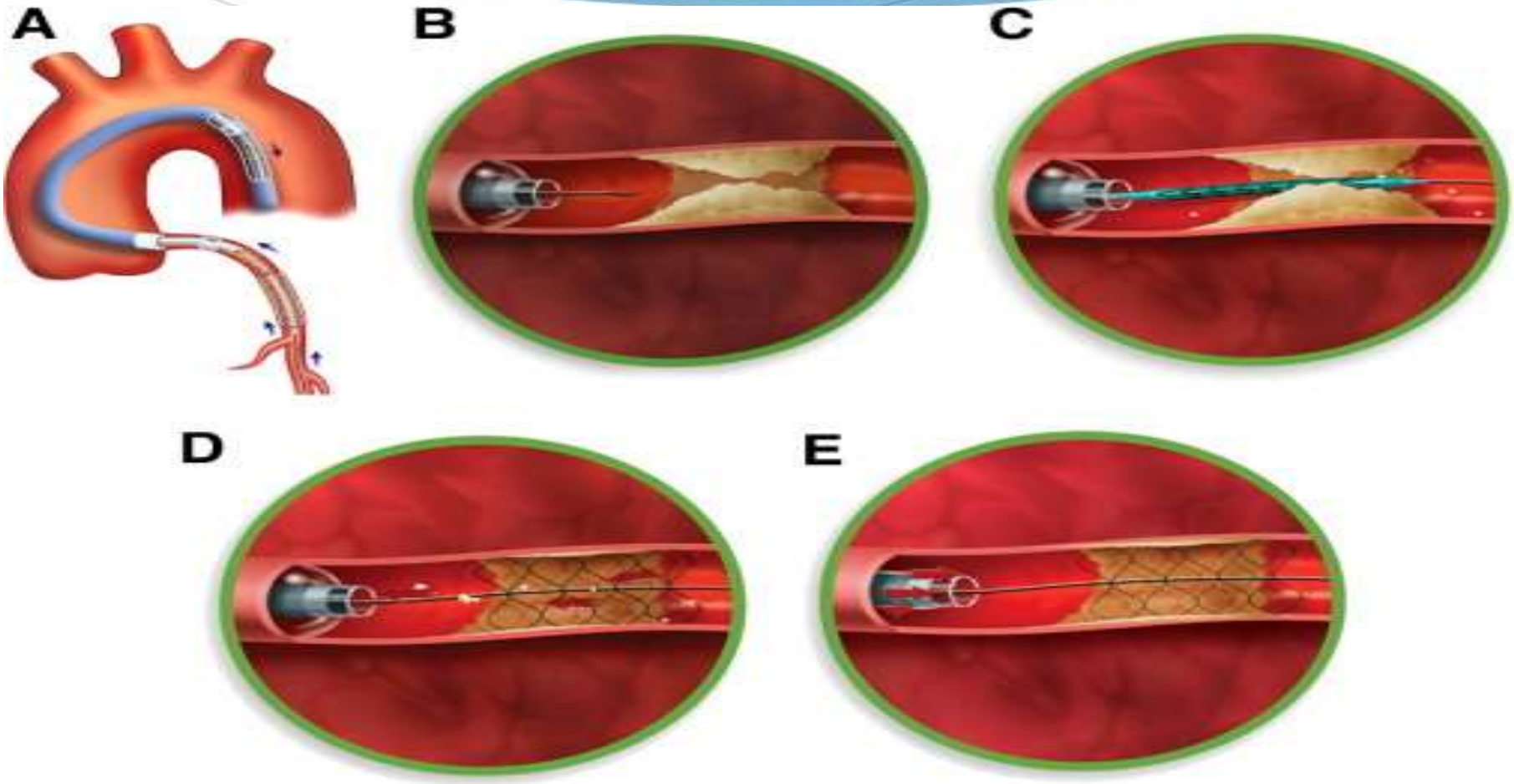
- Aims to close the defective vessel either by Repair with maintaining patency or by occlusion
- The most common area of Cavernous ICA injury is just few mm below the ophthalmic Artery
- The deployment of Balloon or coil and migration risk
- Should be at the level of the injury

Endovascular Techniques

- Endovascular Coil Technique
  - Stainless steel of platinum based material
  - Helical shape with multiple dacrons
  - Thrombogenic
  - Theoretical Risk of Thrombembolism (but not real)
- Higashida et. al, keep BP between 110-160/60-110 for 3 days post occlusion

Endovascular Techniques

- Endovascular stent graft Placement (ESGP) becoming more in the last 10 years
- The most frequently used stent is the coronary stent-graft, consisting of both sides (luminal and abluminal sides) covered with poly- tetrafluoroethylene
- Its role in Cavernous ICA injury
  - 1- Some advised always a trail of ESGP
  - 2- In Patients who failed BTO (poor collateral)
- The major technical difficulty is the limited longitudinal flexibility


A
B
C
D
E

Endovascular Techniques

- Complications
- Wholey et. al
  - Risk of stroke in the 1st 30 days after ESGP is 4.4%
  - The risk is higher in occlusion
  - Patient should receive antiplatelet and anticoagulant (Heparin) as prophylactic for TIA or Stroke
- Park et. al recommended ASA and Clopidogril upto 3 months after the procedure

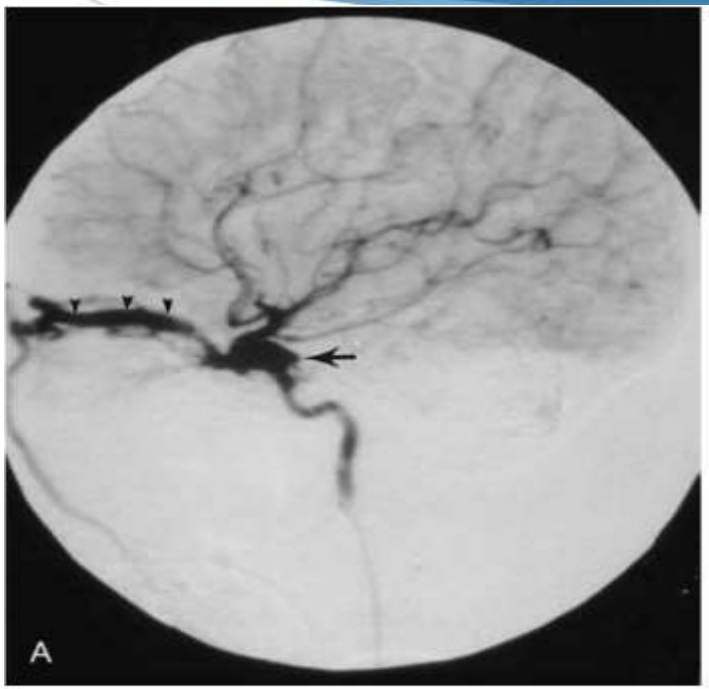
Delayed Cavernous ICA Injury

- All ICA injuries detected intraoperatively
- ICA spasm manifest within few hours till one month
  - Manifested by change of LOC or stroke formation
- Delayed Formation of Pseudoaneurysm or even Rupture
  - Even after uneventful transsphenoidal surgery (9 cases reported by Bvinzeski of Pseudoaneurysm formation) any time From 1wk upto 20 years
  - Raymond et.al presents 3 cases after uneventful surgery
    - Ruptured day one, day 12 and 10 years post op.

Complications of Cavernous ICA Rupture

- Iatrogenic ICA injury could cause
  - 1- Acute Hemorrhage
  - 2- Cariticocavernous Fistula (CCF)
    - Different types A, B, C and D
    - Recognized by proptosis, Chemosis, Opthalmoplegia and orbital bruits
    - Treated by endovascular detachable balloon of coil occlusion

Figure 42.5. Appearance of a patient who developed a spontaneous direct carotid-cavernous sinus fistula after rupture of a previously asymptomatic cavernous aneurysm. *A,* The patient has marked proptosis of the left eye, swelling and ecchymosis of the left upper and lower eyelids, and hemorrhagic conjunctival chemosis. *B,* There is diffuse hemorrhagic chemosis of the conjunctiva. Note that the patient is attempting to look upward to the left, but the left eye is almost completely immobile.



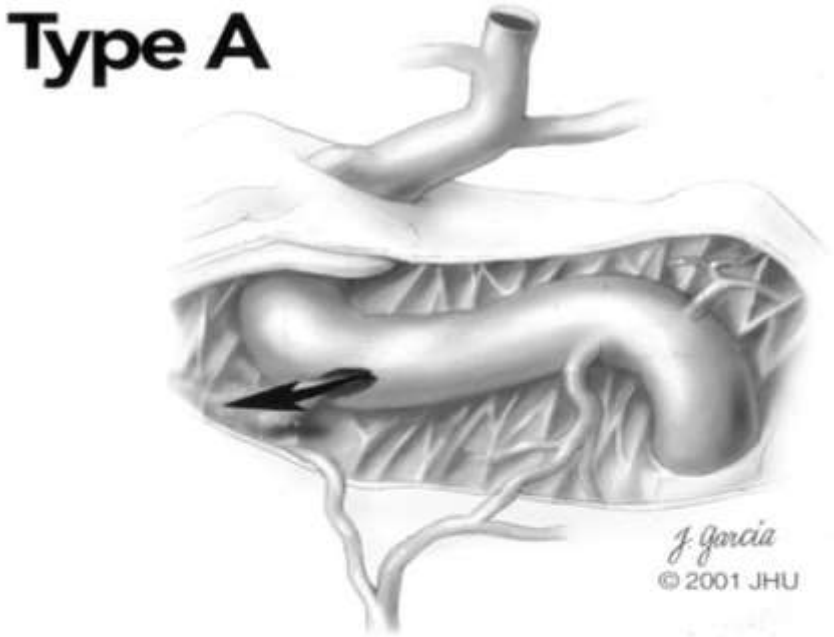


Figure 42.1. Appearance of a direct carotid-cavernous sinus fistula (type A of Barrow [1]). *A,* Angiographic appearance after a selective injection of the left internal carotid artery shows a collection of contrast material in the cavernous sinus (*arrow*). Note that the fistula drains anteriorly into the superior ophthalmic vein (*arrowheads*). There was no contribution from the ipsilateral external carotid artery, nor was there any contribution from the contralateral internal or external carotid arteries. The patient was a 26-year-old woman who suffered a head injury in a motor vehicle accident and developed a red left eye associated with proptosis of the eye and binocular diplopia. *B,* Artist's drawing of a direct carotid-cavernous sinus fistula. Note that there is a single tear in the wall of the internal carotid artery. There is no contribution from either the extradural branches of the internal carotid artery of the extradural branches of the ipsilateral external carotid artery.

Complications of Cavernous ICA Rupture

- 3- Pseudoaneurysm
  - Most common complication 60% of all patients with ICA injury
  - A hematoma that forms with extension due to a defect in the arterial wall
  - Need frequent and long F/u
  - Law proposed that using muscle patch decrease its incidence

Complications of Cavernous ICA Rupture

- Total of 72 reports about ICA rupture
  - 43 patients (60%) developed pseudoaneurysm
    - 12 (27%) had rupture that require intervention
    - 25 (59%) were identified of routine angiography and underwent prophylactic management
    - 6 (14%) managed conservatively

Complications of Cavernous ICA injury

- Ruptured pseudoaneurysm is an ER mandates
  - Airway securement
  - Rapid Resuscitation
  - Local packing → BTO test if patient is stable (not intubated) → and acting accordingly
  - If pseudoaneurysm is found coincidentl during angiography → 30 min BTO + complete Neurological Exam. + assessment of collateral
    - If all are normal → ESGP or observation (for a symptomatic pt is with normensive/mild hypertensive)
    - If BTO abnormal or poor collateral →ESGP or Bypass procedure or aneuresmal clipping

Complications of Cavernous ICA injury

- As indicated by Fox et.al and Higashida et.al, Balloon occlusion is not an option for pseudoaneurysm
- Because of weak and fragile wall with fatal risk of rupture

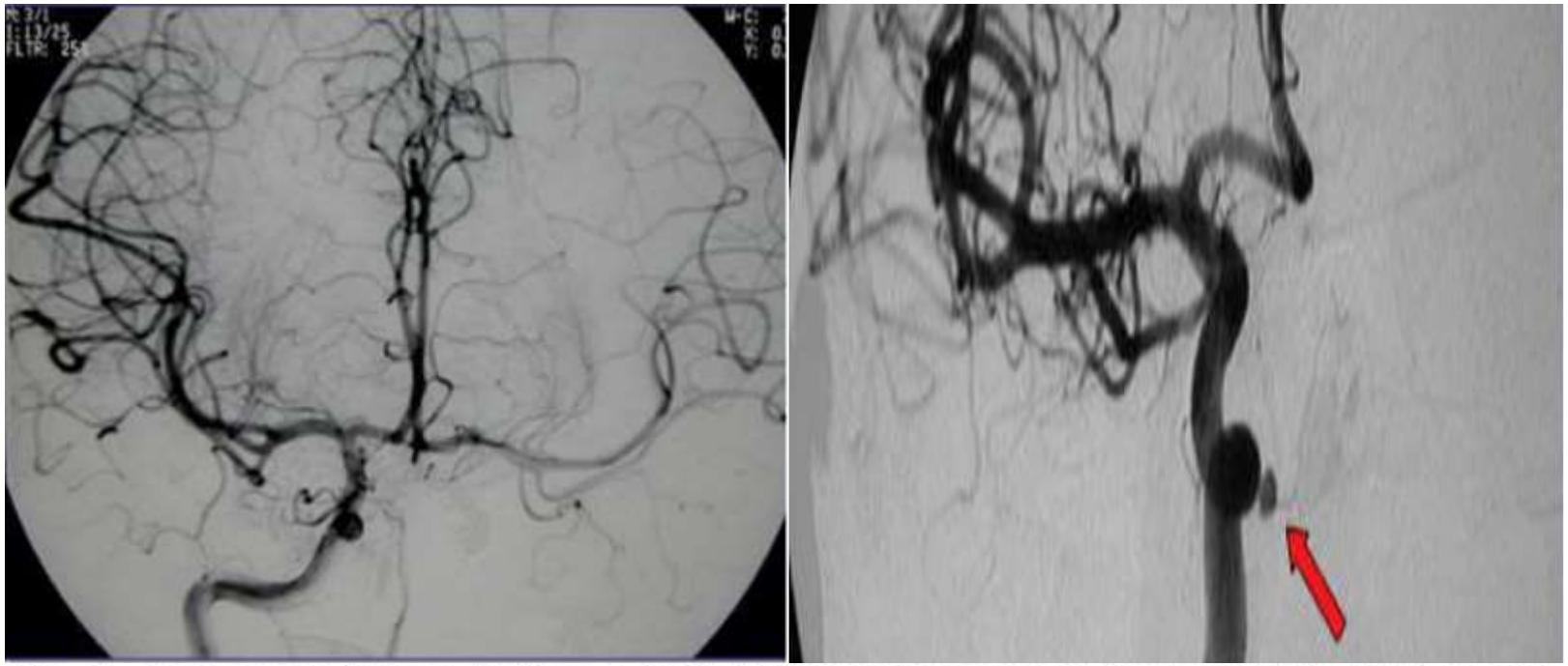


Fig. 5. Angiogram demonstrating a right ICA pseudoaneurysm (*red arrow*) in a 54 yr old male developed following pituitary surgery. Treated with proximal and distal balloon occlusion. (*Courtesy of* Dr Aldo Stamm.)

Outcome

- Significant morbidity and mortality
- Out of 111 patients with ICA rupture (only 89 reported outcome)
  - 1- 15% (13/89) → Mortality
  - 2- 26% (23/89) → Permanent Morbidity
  - 3- 59% (53/89) → No sequel
- Raymond et. al had similar results
  - 17% Mortality
  - 29% related Morbidity

ORIGINAL ARTICLE

A Vascular Catastrophe during Endonasal Surgery: An Endoscopic Sheep Model

Rowan Valentine, M.B.B.S.,[1] and Peter-John Wormald, M.D.[1]

METHODS

- The carotid artery dissected free for a length of 15 cm from the angle of the mandible to the base of the neck
- Both carotid arteries were cannulated at the level of the mandible to allow for continuous invasive arterial pressure monitoring bilaterally
- The left internal jugular vein was identified and then cannulated (as a central line) with a rapid infusion catheter exchange set to allow for rapid fluid resuscitation

METHODS

- The Sinus Model Otorhino Neuro Trainer (SI- MONT, Pro Delphus, Pernambuco, Brazil) was chosen to simulate the endoscopic environment
- In this model, bilateral large sphenoidotomies and partial middle turbinectomies were performed, as is routinely performed during advanced skull base surgery
- The artery then was in the sphenoid sinus as anotmical position.

METHODS

- Absence of carotid compression was confirmed visually and by observing no change in the mean arterial pressure (MAP between the left and right carotid arteries
- The model was then fixed to the operating table and onto the neck of the sheep to prevent displacement during intervention
- Using a 0-degree rigid endoscope, a 3-mm, 15- degree, diamond-tipped bur was then used to drill away the plastic plate, simulating the thin boney covering of the carotid siphon within the sphenoid sinus
- The Hajek punch was then used to expose the carotid artery, creating a boney window revealing the pulsatile carotid artery

METHODS

- An 11-blade scalpel was used to create an approximately 4-mm longitudinal incision through the anterior wall of the carotid artery.
- To confirm a challenging and high-pressure injury, local packing was performed of the injury site only, ensuring that vascular flow was still maintained
- This was confirmed by observing a pulse pressure on the invasive pressure monitor placed distal to the carotid injury site.

METHODS

- Simultaneous fluid resuscitation with warmed normal saline was commenced at 200 mL/min
- Resuscitation was stopped once hemostasis was achieved and the MAP achieved its preinjury level
- A thermal blanket was used to ensure a constant temperature and prevent the adverse affects of hypothermia on the coagulation cascade.
- Specific outcome measures for this study were the preinjury and postinjury MAP despite rapid fluid resuscitation, the resuscitation fluid volume used, and survival time and total blood loss.

RESULTS

- A total of eight sheep were used for validation of this animal model.
- The mean weight was 51.8 □ 4.59 kg. Baseline coagulation and hematologic parameters were similar for all animals with no significant difference between each animal.
- The mean preinjury
  - MAP, pulse, and temperature were 65.7+/- 9.3 mm Hg, 100 +/- □ 14.84 beats per minute, and 40.9+/-□ 0.648C, respectively.
- The mean postinjury
  - MAP (10 minutes postinjury) was 39.1 +/-□ 6.9 mm Hg despite maximal resuscitation efforts at 200 mL/min.
  - The mean resuscitation fluid used at time of exsanguination was 10.89 +/-□ 2.40 L,
  - with a mean total blood loss of 4943 □ mL. With the performance of local packing measures only, which did not obstruct vascular flow,
  - hemostasis was not achieved and resulted in all animals exsanguinating with a mean survival time for each animal of 50.25 +/-□ 17.89 minutes with local cottonoid packing only.

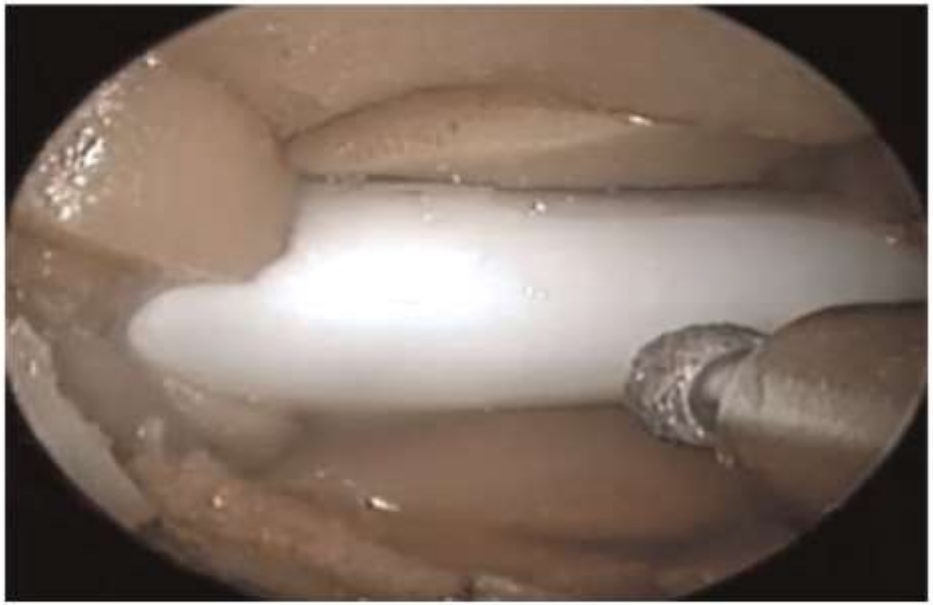


Figure 3 Diamond-tipped bur used to drill through plastic plate to reveal carotid artery.

Figure 2 Sinus Model Otorhino Neuro Trainer (Pro Delphus, Pernambuco, Brazil) model placed at neck of sheep, and fixed to operating table.

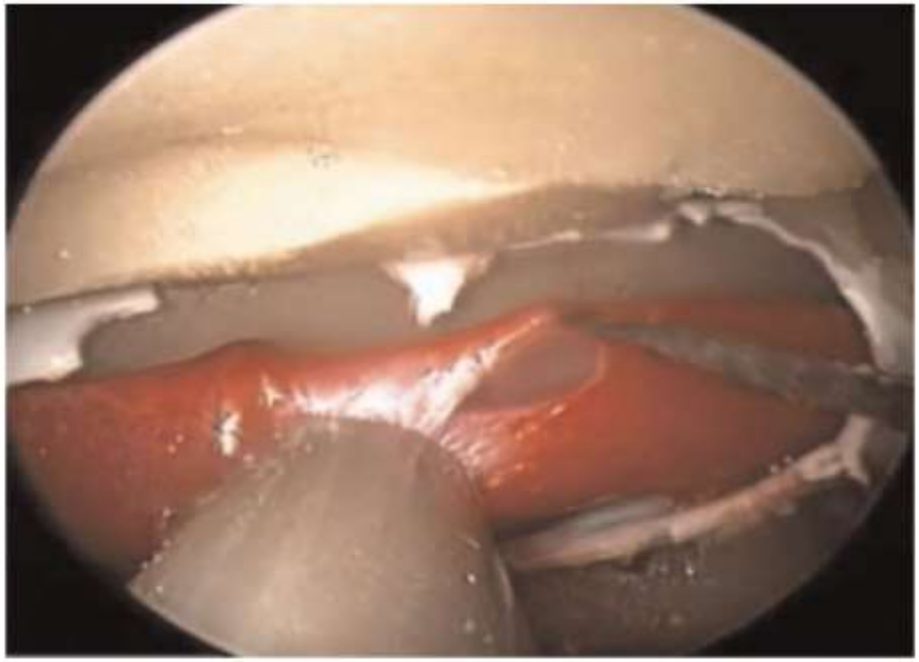


Figure 5 Number 11 scalpel blade used to create the 4-mm carotid injury.

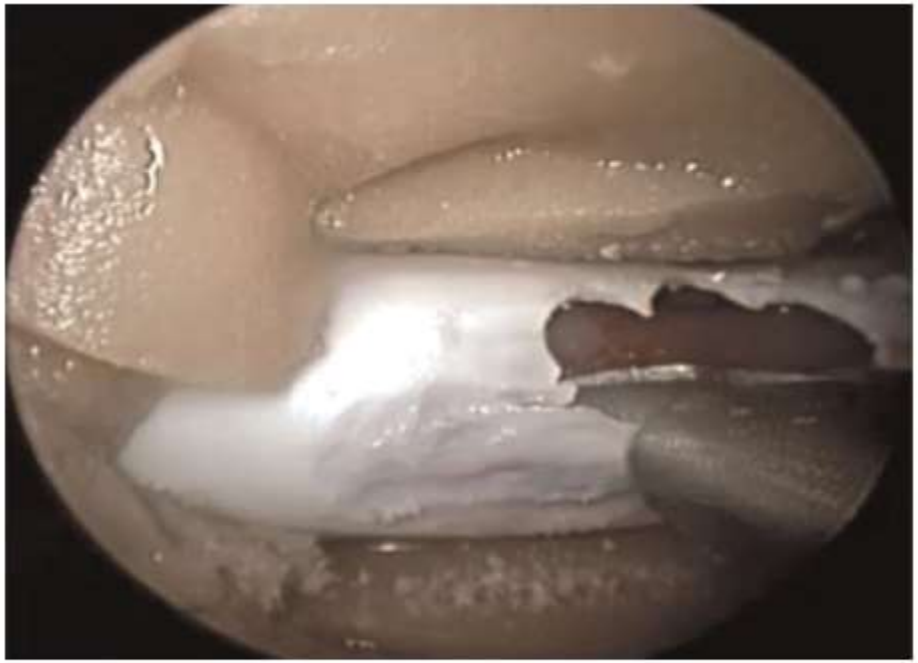


Figure 4 Hajek punch used to remove thinned plastic plate to reveal carotid artery.

Summary and Conclusion

- Risk Factors of ICA injury should be sought considered pre-op
- Putting a prior plan could help during acute crisis
- Crushed Muscle pack is superior to all other hemostatic agents
- If surgical control of bleeding failed → Interv. Radiology
- Options are ESGP →Occlusion → bypass procedure
- Long term F/u is needed as complications may be delayed

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Thank you