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REPUBLIC OF TURKEY
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BLOOD SUPPLY OF INFERIOR TURBINATE AND LATERAL NASAL WALL

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This study has been approved and accepted as PhD dissertation in the program of "DECTORATE OF ANATOMY" by the examining committee, whose members are Listed below, on 26/05/2017

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Date 30 Mayıs 2017

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o Serbest Seçenek/Yazarın Seçimi

23 /06/2017
Asaad Abd Al-hussain Mohammad AL-SHOUK

ETHICAL DECLARATION

In this thesis study, I declare that all the information and documents have been obtained in the base of the academic rules and all audio-visual and written information and results have been presented according to the rules of scientific ethics. I did not do any distortion in data set. In case of using other works, related studies have been fully cited in accordance with the scientific standards. I also declare that my thesis study is original except cited references. It was produced by myself in consultation with supervisor (Assoc. Prof. Dr. İlkan TATAR) and written according to the rules of thesis writing of Hacettepe University Institute of Health Sciences .

Asaad Abd Al-hussain Mohammad AL-SHOUK

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ABSTRACT

Asaad Abd Al-Hussain Mohammad AL-SHOUK, Blood Supply of Inferior Turbinate and Lateral Nasal Wall, Hacettepe University Faculty of Medicine Department of Anatomy Doctor of Philosophy Thesis, Ankara, 2017. The blood supply of the nasal cavity acquires a great deal of interest for many reasons; the first, for the treatment of the common condition which is the epistaxis that need some times surgical interventions. The second, is the newly developed endoscopic surgeries, especially, sinus and skull base surgeries that requires a good choice of endonasal flap to close the dural defects as a consequences of these operations. Successful closure of such defects depends on a vital flap with good blood supply. The blood supply of the nasal cavity is still a subject of controversy; the clinical textbooks added some details to the courses of the arteries from surgical points of interest. In this study, forty formalin-fixed hemisected cadaveric heads were examined; with the aid of dissecting microscope. As a result; the lateral wall was studied, the sphenopalatine artery (SPA) divides before or at the sphenopalatine foramen (SPF) in 36 cases while it divides inside the nose in 4 cases. The superior turbinate artery arises from SPA in 15 cases and arises from nasoseptal (NSA) branch in 25 cases. The SPA gives the NSA and the posterior lateral nasal artery (PLNA). The posterior lateral nasal artery (PLNA) gave middle turbinate artery (MTA) and inferior turbinate artery (ITA).The average length of ITA was 9.057± 1.674 mm, the diameter was 1.452 ± 0.172 mm, the distance from posterior end of IT 7.879 ± 1.52 mm. Anastomosis in the lateral nasal wall between ITA and anterior ethmoidal and lateral nasal – of facial- arteries were established. In conclusion, the lateral nasal wall is supplied mainly by the SPA and its branches, the ethmoidal arteries via their nasal branches, and the facial artery participate in the blood supply of lateral wall and anastomose with branches of SPA. Key words: inferior turbinate artery, inferior turbinate, lateral nasal wall, sphenopalatine artery.

ÖZET

Asaad Abd Al-Hussain Mohammad AL-SHOUK, Concha Nasalıs Inferıor ve Burun Lateral Duvarının Kanlanması, Hacettepe Üniversitesi Sağlık Bilimleri Enstitüsü Anatomi Programı Doktora Tezi, Ankara, 2017. Nazal kavite kanlanması epistaksis gibi bazı cerrahi girişimler gerektiren genel durumların tedavisi ve yeni gelişen özellikle sinüs ve kafa tabanı endoskopik cerrahilerinde operasyon sonucu oluşan dural defektlerin kapatılmasında iyi bir şeçenek olan endonazal flepler gibi birçok sebep yüzünden ilgi çekmektedir. Bu tip defektlerin başarıyla kapatılması iyi kanlanan bir flebe bağlıdır. Cavitus nasi kanlanması anatomi kitaplarında katkı sağlayan ana arterleri tanımlayarak ana hatlarını çizerken, cerrahi kitapları arterlerin seyrinin detaylarını cerrahi bakış açısından irdelemektedirler. Bu çalışmada diseksiyon mikroskobu kullanılarak 40 adet formalin fikse kadavra yarıkafasında nasal duvar ve concha nasalis inferior'a yönelik anatomik diseksiyonlar yapılmıştır. Lateral nazal duvar çalışıldığında a. sphenopalatina (SPA) 36 olguda foramen sphenopalatinum (SPF) öncesinde, 4 olguda da burun içinde dallarına ayrılmıştır. SPA, a. nasoseptalis (NSA) ve A. nasalis lateralis posterior (PLNA) dallarını verir. Üst concha arteri(STA) 15 olguda direk SPA'dan, 25 olguda NSA'dan köken almıştır. Orta (MTA) ve alt (ITA) concha arterleri PLNA'dan köken alır. Alt concha arteri ortalama uzunluğu 9.057 ± 1.674 mm, çapı 1.452 ± 0.172 mm ve alt concha arka ucundan uzaklığı 7.879 ± 1.529 mm'dir. Lateral nazal duvarda ITA ile a. ethmoidalis anterior ve a. facialis'in lateral nazal dalları arasında anastamozlar izlenmiştir. Sonuç olarak; lateral nazal duvar esas olarak SPA ve dalları tarafından beslenmekte, ethmoid ve facial arterlerin nazal dalları bu artere yaptıkları anastamozlarla katkı vermektedirler.

Anahtar kelimeler: Alt concha arteri, concha nasalis inferior, lateral nazal duvar, A. Sphenopalatina, A. Ethmoidalis anterior.

CONTENTS

LIST OF ABBREVIATIONS

AEA. Anterior ethmoidal artery.

ITA inferior turbinate artery.

IT inferior turbinate.

MTA middle turbinate artery.

MT middle turbinate.

mm. millimetre.

NSA nasoseptal artery.

PEA posterior ethmoidal artery.

PLNA posterior lateral nasal artery.

SPA sphenopalatine artery.

SPF sphenopalatine foramen.

STA superior turbinate artery.

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1. INTRODUCTION

The developments of endoscopic cranial surgery, especially, skull base surgery and other neurological clinical conditions which utilize the endonasal routes spotted the light on the anatomy of the nasal cavity and its blood supply, since the nasal cavity represents the corridor for these operations. The defects which were done made in the skull base need closure by a flap to prevent the cerebrospinal fluid leaks. The best donor for those kinds of flaps was chosen from the nasal mucosa. As a result, an increasing interest appeared about the blood supply of the nasal cavity; because of the vitality and successfulness of these flaps depend largely on their efficient blood supply. Dozens of researches and their articles were related to the surgical techniques and the choices of the flaps dealing with cranial base and other neurological surgeries[1]. They also focused on the blood supply of the nasal wall and the nasal turbinates, as these areas were the site of these flaps[2]. It is obvious that this interest in the nasal blood supply is largely increased after the emergence and development of endoscopic surgeries. Nowadays, the endoscopic approaches become so popular with the good understanding of the detailed anatomy of these regions. Although the blood supply of the nasal cavity was studied earlier, as a way to performing ideal treatments of rhinological conditions for examples epistaxis, turbinate hypertrophy, and sinus surgeries, the reader can easily discover that the attention was increased dramatically after the evolving of cranial endoscopic procedures[1].

The nose, as it is the first part of the upper respiratory tract; it cleans, humidify the inspired air. The odors are percepted also by the nose as it contains the olfactory epithelium, which is a habitat of olfactory receptor neurons responsible for detecting airborne odorant molecules[3].

The external nose opens anteriorly on to the face through the nares or nostrils, the nasal cavity is divided by a septum into right and left cavities. These cavities open backward into the nasopharynx through the choanae. The nasal cavity contained in a

bony and fibro-elastic framework. These bones contain spaces with respiratory epithelium lining, called collectively as paranasal sinuses. These sinuses communicate with the lateral nasal wall through small openings (ostia) and may play a role in humidifying and warming the inspired air. The nasolacrimal ducts also drain into the nasal cavity through openings in the lateral nasal walls[3].

Each half of the nasal cavity has a floor, roof, lateral and medial walls. The floor is formed by the palatine process of the maxilla and the horizontal plate of the palatine bone, i.e. the upper surface of the hard palate. The roof is narrow and is formed by the body of the sphenoid from behind, the cribriform plate of ethmoid, the frontal bone, the nasal bone, and the nasal cartilages. The lateral wall of the nasal cavity characterized by the presence of bony projections, the conchae, though they are clinically called as turbinates. These shelves-like projections extend medially and curved downwardly to reach the meatuses. Usually there are three conchae; superior, middle, and inferior, in some cases a supreme concha may be found [3,4] .

The nose receives its main blood supply from the sphenopalatine artery which is the terminal branch of the maxillary artery and it is the one of the terminal branches of the external carotid artery. The sphenopalatine artery or its branches, enters the nasal cavity through its lateral wall from a foramen of the same name. Although some accessory foramens may present that admit the accessory arteries. In or before entering the nasal cavity, the sphenopalatine artery gives main branches which are the nasoseptal and posterior lateral nasal arteries. A branch to the superior turbinate may arise directly from the sphenopalatine artery or may arise from the nasoseptal artery. The posterior lateral nasal artery passes downward and gives a branch that supplies the middle turbinate, and then continues as the inferior turbinate artery which passes to supply the inferior turbinate. The nasoseptal artery after giving off the superior turbinate branch, when present, continues medially on the anteroinferior face of the body of the sphenoid bone below the ostium of the sphenoid sinus, which makes

important relationship with it during endoscopic trans-sphenoidal approach to pituitary gland, to reach the nasal septum where it also supplies in addition to other arteries [4,5] .

The upper part of the lateral nasal wall and the nasal septum receive further blood supply from the posterior and anterior ethmoidal arteries, which are branches of ophthalmic artery of the internal carotid artery. These arteries make anastomosis with the branches of sphenopalatine artery [4,5,6].

Furthermore, the facial artery participates in the blood supply of the lateral nasal wall through its lateral nasal branch which encroaches from the nares and anastomosed with the terminal branches of the inferior turbinate artery [6].

In addition to all of the above, anatomical variations are not uncommon in this region. The surgeons can be faced with these variations during various surgical procedures and they may lead to unexpected intra- or postoperative complications [1].

There is a controversy about the dominant arterial supply, the presence or absence of the anastomosis between ethmoidal, sphenopalatine, and facial arteries, and the efficiency of such anastomosis, when present, to compensate the defective blood supply from the major sources.

The objective of this study is to highlight the blood supply of the inferior turbinate and the lateral nasal wall in details from an anatomical point of view using cadaveric dissection, and in view of its' clinical importance.

2. REVIEW OF LITERATURES

2.1. Anatomy of the nose:

The nose is found for breathing and it is the first part of the upper respiratory tract. The inspired air is filtered, warmed, and humidified while passing through the nose, which is designed for such purpose. Since the odours are airborne, the nose also contains the olfactory epithelium, which habitat olfactory receptor neurones responsible for detecting airborne odorant molecules[4].

The nose is subdivided morphologically into an external nose and internal chambers (or nasal cavity); the former opens anteriorly on to the face through the nares or nostrils, while the later is divided almost sagittally by a septum into right and left cavities. These cavities open backward to the nasopharynx through the posterior nasal apertures or choanae. The nasal cavity contained in a bony and fibroelastic framework supporting the nasal cavities. These bones contain air –filled spaces with respiratory epithelium lining, called collectively as paranasal sinuses. These sinuses communicate with the lateral nasal wall through small openings (ostia) and may play a role in humidifying and warming the inspired air. The nasolacrimal ducts also drain into the nasal cavity through openings in the lateral nasal walls[4].

2.1.1. The nasal cavity:

The lateral walls of the nasal cavity's shape are roughly semicircular, with the highest point mid-way along, i.e. at the cribriform plate of ethmoid. The roof curves up from the vestibule to this level; behind the cribriform plate the roof slopes down over the body of the sphenoid into the nasopharynx. The lateral wall converges up from the broad nasal floor to the narrow roof that's to say it is not vertical[5]. Each side of nasal cavity is approximately 5 cm in height, and 5-7 cm in length. The transverse measurements of nasal cavity are approximately 1.5 cm at the floor and only 1-2 mm at the roof. The medially projecting conchae from the lateral nasal wall decrease the width of the cavity and nearly fill it [5,6] . The conchae

covered with mucous membrane, that's of the inferior turbinate contains large vascular spaces, erectile tissue that control the calibre of nasal cavity and can swell and even block the nose as in some cases[5].

2.1.2. Embryology of Nasal Cavities

The nasal pits of the embryo start to deepen remarkably at the sixth week of development, due to the growth of the surrounding nasal prominences and because of their penetration into the underlying mesenchyme. The pits were separated from the primitive oral cavity by the oronasal membrane by way of the newly formed foramina, the primitive choanae. These choanae lie immediately behind the primary palate on each side of the midline. With the formation of the secondary palate, later on, and further development of the primitive nasal chambers, the definitive choanae, so formed, will lie at the junction of the nasal cavity and the pharynx (figure 2.1.). Diverticula of the lateral nasal wall develop and extend into the maxilla, ethmoid, frontal, and sphenoid bones forming the paranasal sinuses. These sinuses reach their maximum size during puberty and participate in the definitive shape of the face [7].

By seventh week of gestation, three axial furrows develop from the lateral nasal wall, giving rise to the three conchae[8]. They are arranged in similar manner as the adult turbinates [9]. The turbinates consist of cartilage at ninth week of gestation, the inferior one start to ossify early approximately at 17th week followed by middle turbinate[10]. At the tenth week the maxillary sinus starts to develop by invaginating the middle meatus. Simultaneously the bulla ethmoidalis and uncinate process form a narrow groove, hiatus semilunaris. As several invaginations; the anterior ethmoidal air cells appeared from the upper middle meatus and the posterior ethmoidal air cells appeared from the floor of superior meatus by the fourteenth week. The lateral nasal wall is well developed at the thirty-sixth week of gestation, the sinuses developed significantly at various period of growth, with the ethmoidal first to be fully developed followed by the maxillary, sphenoid, and finally frontal sinuses [8].

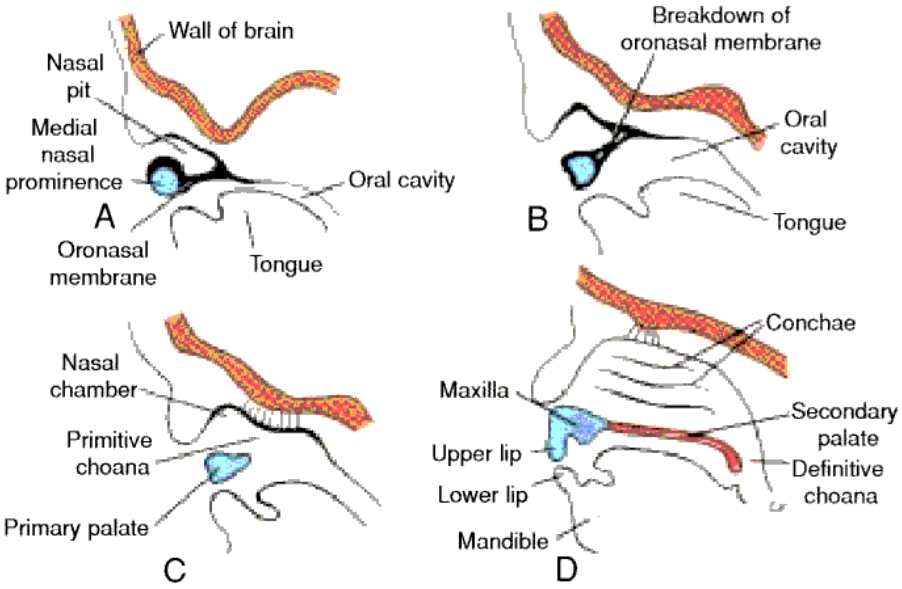

Figure 2.1. Sagittal section through the nasal pit and lower rim of the medial nasal prominence of a 6-week embryo. The primitive nasal cavity is separated from the oral cavity by the oronasal membrane. B. Similar section as in A showing the oronasal membrane breaking down. C. A 7-week embryo with a primitive nasal cavity in open connection with the oral cavity. D. Sagittal section through the face of a 9-week embryo showing separation of the definitive nasal and oral cavities by the primary and secondary palate. Definitive choanae are at the junction of the oral cavity and the pharynx[7].

2.1.3. Bony framework of the nasal cavity:

The nasal cavity which is an irregular – shaped space extends from the roof of the mouth below to the base of skull above. It is divided into left and right halves by the septum, which is mostly deviated from midline. The septum extends to the posterior limit of the cavity where the nasal cavity communicates with the nasopharynx through the posterior nasal aperture or choana, which situated above the posterior border of the bony plate [4, 5,6,11].

The nasal cavity is pear-shaped space; it is wider below than above, widest and deepest in its central part. The frontal, ethmoidal, maxillary and sphenoidal sinuses communicate with the nasal cavity via their ostia. Furthermore the nasolacrimal ducts open to the inferior meatus. Each half of the nasal cavity has a floor, a roof, a medial and a lateral wall, the medial wall represent the corresponding side of nasal septum [4,5,6,11] (Figure 2.2).

The **floor** is formed anteriorly by the palatine processes of the two maxillae where they meet in midline; posteriorly the floor is completed by the horizontal plates of the two palatine bones, articulate with each others at the median plane and with the palatine processes of the maxilla anteriorly. The floor, thus, formed by the upper surface of bony palate which intervenes between the oral and nasal cavities. The floor is gently concave from side to side, and slightly upward sloping as moving backward from anterior to posterior apertures[4-6].

The **roof** slopes downward anteriorly and posteriorly with a horizontal part in between. In front; the roof is made by frontal and nasal bones and they form the external nose, the posterior sloping part is made by the body of the sphenoid bone. The middle horizontal part is the cribriform plate of ethmoid bone with its numerous small openings for the passage of olfactory nerves, this plate separate the nasal cavity from the anterior cranial fossa [4-6, 11-15].

The **medial** wall is made by the bony septum which extends from the floor to the roof. It is deficient anteriorly where the septal cartilage fulfils the bony deficiency. The bony septum is formed almost by the vomer which extends between the under surface of the sphenoid body to the bony palate, i.e. it occupy the posteroinferior part of the septum. While the perpendicular plate of ethmoid forms the anterosuperior part of the septum. The septum often deviated to one side, and the deviation usually occurs at the vomero-ethmoidal suture [4-6, 11-15].

The **lateral** wall of nasal cavity formed by the bones of viscerocranium; the maxilla lie anteroinferiorly, the perpendicular plate of palatine bone contributes to the posterior part of the wall. This plate has two processes; sphenoidal and orbital,

with a deep notch between them called sphenopalatine notch. This notch converted to a foramen by the positioning of the body of the sphenoid bone. The ethmoid bone, by its labyrinth, participates in the formation of the superior part of the wall (in addition to the roof). The lateral wall characterized by its irregular shape owing to the presence of, usually, three bony projections of variable size called; superior, middle and inferior conchae (or turbinates as the clinicians called). Each concha projects medially and curved inferiorly making a groove beneath it, the meatus. In some cases an additional concha present above the superior one called supreme nasal concha. The inferior concha is an independent bone, articulate with the medial wall of the maxilla anteriorly and the medial surface of perpendicular palate of palatine posteriorly, where these two bones have a low ridge called conchal crest for the articulation. The inferior meatus lies below the gently inferiorly curved concha, it extends downward to the floor of the nasal cavity. The inferior concha and meatus is the largest of the three conchae and meatuses. The meatus receives the opening of nasolacrimal duct anteriorly [4-6, 11-15].

The middle and superior conchae are projecting from the medial surface of ethmoidal labyrinth; they are fused anteriorly but diverge from each other as passing backward. The middle is larger than the superior, it articulate anteriorly with the frontal process of the maxilla and posteriorly with the perpendicular plate of palatine bone just below the sphenopalatine foramen. The middle meatus extend between middle and inferior conchae; it shows several features in its lateral wall. In the upper part, there is a rounded elevation, ethmoidal bulla, which contains the middle ethmoidal air cells. Below this and anteriorly, a thin curved bony lamina named uncinate process of the ethmoid, passes down across the maxillary hiatus reaching the base of inferior concha. The so-formed gap between the bulla and this process, which is curved in- shape called hiatus semilunaris. The upper end of it is continuous with the ethmoidal infundibulum, which is a curved, short canal receives the openings of anterior ethmoidal air cells and in upper extremity it receive the opening of frontal sinus. The posterior end of semilunar hiatus receives the ostium of maxillary sinus [4-6, 11, 15, and 16].

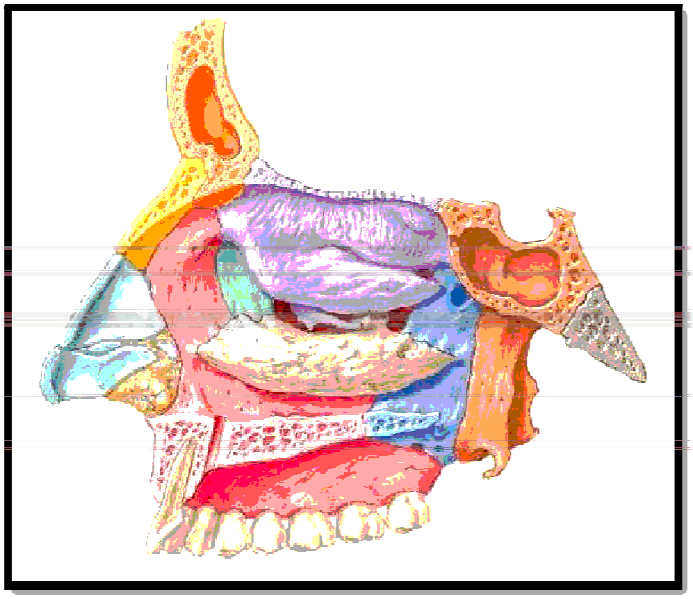

Figure 2.2. Bony structure of lateral wall of nasal cavity

In some cases anatomical variations may be found for additional air cells, e.g. Haller cells which are originally ethmoidal air cells that extend to the medial roof of maxillary sinus. It may vary in shape and size leading to narrowing of the infundibulum when they are large enough. Onodi cells are another variation which is rare; they are extension of the posterior ethmoidal air cells laterally and posteriorly extending the paranasal sinus near the optic nerve as it exits the orbit. These cells may surround the optic nerve and put it into risk during surgery[17].

The superior concha, the smallest of the three, lies above and behind the middle concha. It roofs the superior meatus, which is in turn shortest and shallowest of the three meatuses. The meatus receive the posterior ethmoidal air cells' openings [5, 6].

Supreme concha (concha suprema) when present, it lies above and behind the posterior end of superior concha. It is a slight ridge, made on the medial wall of ethmoidal labyrinth [4-6, 11-15].

Lies above and behind the superior concha, a narrow recess named sphenoethmoidal recess, it contain the sphenoidal sinus ostium.

The sphenopalatine foramen found at the lateral wall of nasal cavity at the posterior end of superior meatus or just above the middle concha. It connects the nasal cavity medially with the pterygopalatine fossa laterally. The foramen transmits an artery, or its branches, and vein of the same name, in addition to, nasopalatine, lateral, and medial posterior superior alveolar nerves. Anterior to the foramen, a small bony crest formed by the attachment of the basal lamella of the middle turbinate to the ascending palatine bone, the crista ethmoidalis, which made a reliable surgical landmark [4-6,11,15,16].

2.1.4. The lining mucosa of nasal cavity:

Most of the surface of the nasal cavity is lined by respiratory epithelium (pseudostritified ciliated epithelium rich in goblet cells), i.e. it covers the conchae, meatuses, septum, floor and roof, with the exception of the most superior part, the olfactory region, where the olfactory epithelium is present. The anterior part of nasal cavity and vestibule is lined by keratinized stratified squamous epithelium, like the skin of the face, the inferior part carry a coarse hair (vibrissae). The epithelium is adherent to the perichondrium or periosteum of the neighbouring skeletal structures. In some areas, the proportion of ciliated to non-ciliated cells is variable, and the cells of the respiratory epithelium may be low columnar or cuboidal. The mucosa of the inferior concha contains large vascular spaces, erectile tissue that changes the nasal cavity calibre [4, 5, and 14].

2.2. The blood supply of nasal cavity:

The nasal cavity is supplied by both external and internal carotid arteries through their respective branches. The sphenopalatine artery constitutes the main blood supply of the nasal cavity; the ophthalmic; via anterior and posterior ethmoidal branches, and facial arteries take part in the blood supply too. They ramify to form anastomotic plexuses deep or within nasal mucosa[5, 18].

2.2.1. Internal carotid artery:

The ophthalmic artery arises from the internal carotid artery as it exits the cavernous sinus. It enters the orbit through the optic canal with the optic nerve. During its course in the orbit it gives some branches; the posterior ethmoidal artery is giving off the ophthalmic artery and passes through the posterior ethmoidal canal supplying the posterior ethmoidal air cells, then it passes to the cranium giving a meningeal branch finally it descends to the nasal cavity through the cribriform plate of ethmoid bone supplying the upper part of the lateral wall of nasal cavity and anastomosing with the branches of sphenopalatine artery [4].

The anterior ethmoidal artery is another branch of ophthalmic artery which passes through the anterior ethmoidal canal accompanied by same named nerve. The artery supplies the anterior ethmoidal air cells and frontal sinus, then it courses in the cranium giving a meningeal branch and a nasal branch. The later descends to the nasal cavity supplying the upper part of lateral nasal wall and nasal septum[4].

2.2.2. External carotid artery:

The facial artery, previously called external maxillary artery, participate in the blood supply of the nasal cavity via its angular, superior labial, or lateral nasal branches. Although it's main contribution is to the arterial plexus, Kiesselbach's plexus in the anteroinferior part the nasal septum (Little's area), some studies provide evidences that it participates in the anastomosis located in the lower anterior part of the lateral nasal wall[19, 20] (Figure 2.3).

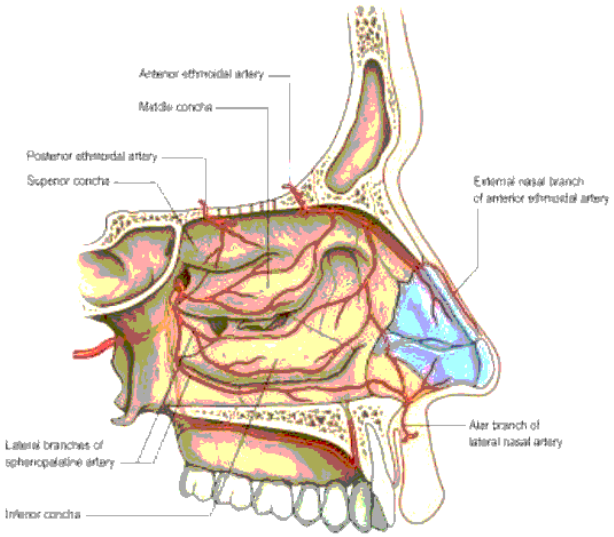

Figure 2.3. Diagram of blood supply of lateral nasal wall[4]

The sphenopalatine artery which is the terminal branch of maxillary artery, or internal maxillary artery, supplies the turbinates, meatuses and the nasal septum in its posteroinferior part. The artery approaches the nasal cavity through a sphenopalatine fissure (erroneously called a foramen) which connects the nasal cavity with the pterygopalatine fossa. The artery either enters the cavity as a single artery or may divides before it leaves the foramen[4].

The sphenopalatine artery gives usually two main branches; septal artery (nasopalatine artery) which runs medially over the anteroinferior wall of sphenoid body, where the sinus located, reaching the nasal septum where it participate in its blood supply. The septal artery, or posterior septal artery as it is named by some authors, as it passes on the anterior wall of the sphenoid sinus, it is located between the sphenoid ostium and the choana. This position of the artery should keep in mind during the transsphenoidal surgeries as an attempt to widening the ostium inferiorly jeopardizes the artery [21].

The other main branch of the sphenopalatine artery is the posterior lateral nasal artery, or posterior superior branch according to some authors[22], it runs downward close to the posterior end of middle turbinate and about 1 cm anterior to the posterior end of the middle turbinate[23].

The middle turbinate regarded, for a long time, as the demarcation line between internal and external carotid arteries, as the clinicians supposed, the area of nasal cavity above it is supplied by the internal carotid branches while the area below is by external carotid[24]. The same suggestion is for the nasal septum with the same corresponding level, except for the Little's area, which is much below, it is supplied by both arteries. Tami in his book mentioned that the internal maxillary artery enters the nasal cavity and descend downward as descending palatine artery supplying the lateral nasal wall below the level of middle meatus where as the level above is supplied by both anterior and posterior ethmoidal arteries[25]. This dividing line between external and internal carotid arteries might not coincide with the middle turbinate level as the works of some authors indicate. Zuckerkandl (1892) and Burnham (1935) showed that the middle turbinate is supplied just by the branches of external carotid artery, where as anastomosis between the two carotid arteries take place anterior and above to the anterior attachment of the turbinate, not within it[26].

Recently, the popularity of the endoscopic sinus surgeries for the treatments of sinonasal malignancies and endoscopic treatment of nasal pathologies and/or diseases e.g. epistaxis and turbinate hypertrophy. Furthermore the development of endoscopic transnasal approaches to the anterior and middle cranial fossae to treat variable neurological pathologies especially that of the pituitary gland, in addition to various neurosurgical procedures for treatment of brain tumours, vascular malformations, etc, lead to the increase in the interest about the detailed pattern of blood supply of the lateral nasal wall largely in the last decades. The great advances in endoscopic endonasal/transnasal surgery necessitate a good anatomical knowledge about the position and courses of the arteries within the nasal cavity. As the accidental injury to one of these blood vessels can lead to variable bleeding this could be regarded as one of the main complications encountered during such operations. Furthermore failure to localize these blood vessels, during treatment of one of the most common encountered nasal problem which is the epistaxis, makes the surgeons' job much harder. Adding to that, the newly developed methods in

reconstructive surgery for the treatment of dural defects following transnasal endocranial approaches by using of nasal mucosal flaps require a good knowledge of the blood supply of nasal cavity.

Babin *et al*. showed that, in a cadaveric study, the sphenopalatine artery enter the nasal cavity as a single trunk in two cases out of 20 sides they studied, while in the rest 18 cases, the artery divides before entering the nasal cavity, and enter as 2 branches in 10 cases, 3 branches in 6 cases, 4 and 5 branches in one case. The branch that goes to the middle turbinate, anastomose with the ethmoidal artery terminals. Where as a branch to the superior turbinate was noticed in two cases[27].

Burnham, 1935, did a detailed study about the blood supply of lateral nasal wall using a microscopic dissection and a series of 30 -40 µm section thicknesses of the wall and examined them under light microscope. He stated that the sphenopalatine artery and its terminal branches is the direct arterial supply of the lateral nasal wall, the artery enters the nasal cavity through the sphenopalatine foramen and breaks up into three branches; nasopalatine, middle turbinate, and inferior turbinate. These branches lie in bony canals in part of their courses. The nasopalatine artery enters the nasal cavity through the sphenopalatine foramen and leaves the lateral wall to course along the anteroinferior border of the sphenoid bone reaching the septum. Before leaving the lateral wall it gives off a superior turbinate branch and a branch to the sphenoid ostium. The middle turbinate artery enters the under surface of the middle turbinate and enters the bony canal at the junction of the middle and posterior thirds of the turbinate. The artery breaks up into three or four terminal branches that supply the turbinate and the bulla, and then anastomose with the terminals of anterior ethmoidal artery. The third branch of the sphenopalatine artery, the inferior turbinate artery, supplies the inferior turbinate and the inferior, middle, and part of the common meatuses. The trunk of this artery leaves the sphenopalatine foramen passing downwards and forwards slightly to the posterior tip of inferior concha. Through its course downward, it lies

in the periosteum of the lateral wall and it measures 1 mm width and 2 cm length. On reaching the posterior tip, it trifurcate into terminal branches that lie at a right angle to the long axis of the trunk, then they passes along the inferior turbinate in bony canals till the middle of the turbinate where they leave the canals supplying the surface of the turbinate[19] (figure 2.4).

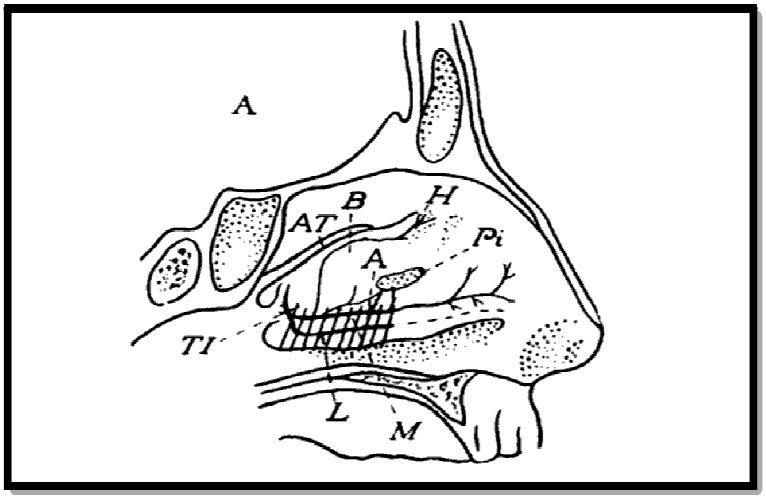

Figure 2.4. Show typical course of inferior turbinate artery. Ti: trunk of ITA, M: medial branch, L: lateral branch, A: antral artery, AT: attachment of MT., Pi: uncinate aperture, H: hiatus semilunaris, B: artery to the bulla[19].

The course and branching pattern of sphenopalatine artery was also studied by many researchers, some stated that the artery divided into two to four branches before exiting the sphenopalatine foramen[28]**.** Lee *et al* studied 50 specimens and they found that the artery divides before exiting the sphenopalatine foramen into two major branches in 76% specimens, three branches in 22%, and four branches in 2%. The three- branched pattern of division shows two main and one small branch that either goes to superior turbinate or, in the other hand, to the middle turbinate. In the two branched pattern, the septal artery exit from the sphenopalatine foramen passes anteroinferior to the wall of sphenoid sinus, while the other branch, the posterior lateral nasal artery runs inferiorly 1cm anterior to the posterior end of

middle turbinate. In 42% of specimens the artery lies posterior to the posterior wall of maxillary sinus, in 20% it lies posterior in upper part and inferior in the lower part to the posterior wall of maxillary sinus, while in 18% the posterior lateral nasal artery lies anterior to the posterior wall of the sinus. The inferior turbinate artery, which is the end artery of the posterior lateral nasal artery divided in two patterns, the first one when the artery divides into two branches one runs anteriorly along the upper part of the inferior turbinate and the other runs along the midpart of the turbinate. The second pattern the artery passes through the concha and divides into two branches which run anteriorly along the upper and midpart of the turbinate[28].

Midilli *et al*. in their study on 20 sagittally sectioned cadaveric heads found that the sphenopalatine artery branched off within the sphenopalatine foramen in 80% of specimens and after entering the nasal cavity in the rest 20%. They also reported the branching pattern of the artery as two main branches in 80%, three branches in 15%, and four branches in 5%. In the three branched specimens they found that the two main branches were the posterior septal artery and posterior lateral nasal artery, the third branch was either additional posterior septal artery (in two cases) or branch to superior turbinate (in one case). They did not mention details about the inferior turbinate artery or its branches[29].

In case report published by Biswas *et al*. they found that the main arterial supply of the nasal cavity was from anterior ethmoidal arteries in both sides. This is the only case reported as non- sphenopalatine dominant blood supply of nasal cavity. Neither other cases nor cadaveric studies showed such anatomical variations[30].

Prades *et al*. studied the sphenopalatine foramen and its arterial content, their study based on dry skulls and cadaveric heads. They found that in two- thirds of the dissected heads the sphenopalatine artery branched off within the foramen while in one-third of the specimens the artery divides outside the foramen, i.e. emerge as a single trunk from it. The sphenopalatine artery divides into two major branches; posterior lateral nasal artery and nasal septal artery. The former runs

inferiorly and vertically on the perpendicular plate of the palatine bone to reach the inferior turbinate. The artery gave a branch to the middle turbinate, this arise from the stem of the artery or isolated at the exit of the sphenopalatine foramen. The average diameter of the posterior lateral nasal artery was 1.80 ± 0.20mm, while of the nasal septal artery was 1.30± 0.30 mm[31].

Another study made by Padgham and Vaughan-Jones about the inferior turbinate arterial supply, they mentioned the position of sphenopalatine foramen as under cover of middle turbinate in majority of cases while it lies in the superior meatus in just two cases. The emerging sphenopalatine artery gave a descending branch which passes down and forward slightly to enter the inferior turbinate. On coursing to the turbinate it enters the superior aspect of its lateral attachment 1.0 to 1.5 cm from its posterior tip. There the artery divides into two branches; one lies high and lateral, the other lower and medial, both arteries run inside a bony canal or closely to the inferior concha for most of their courses. The authors noted that the medial lower branch gave off branches that pierce the bone of inferior concha, but despite these branches the artery increases in size as it passes anteriorly which gave a clue that the artery receives additional blood flow from anteriorly, may be from anastomosis with facial artery branch which encroaches from the pyriform aperture[20] (figure 2.5).

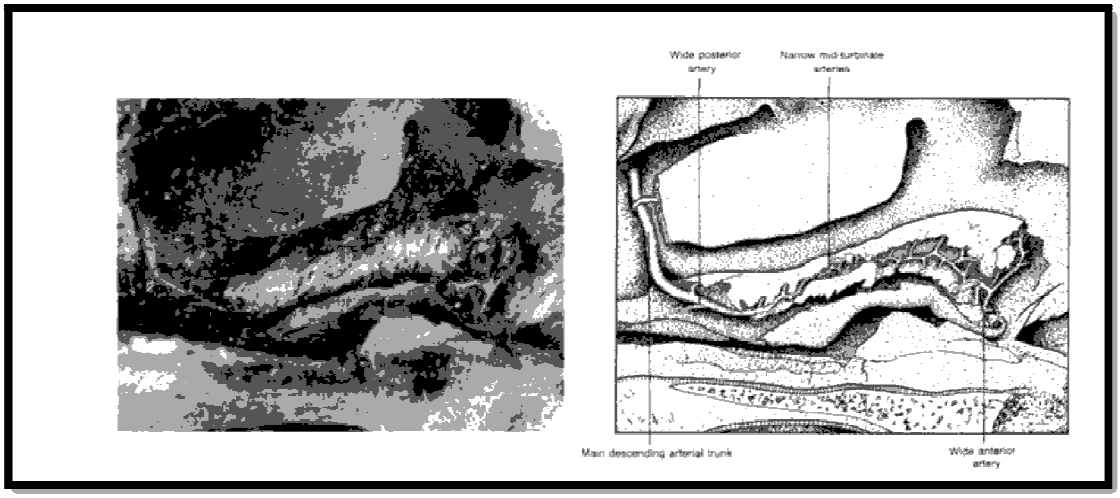

Figure 2.5. Inferior turbinate arterial supply and intraturbinate arterial distribution[20].

Murakami *et al*. depend on the facts that the inferior turbinate has a dual blood supply from both inferior turbinate and angular arteries, depending on the studies of previous works, in making anteriorly based inferior turbinate nasal mucosal flap for correction of septal defects. The success rate of his procedure was too high[32].

On the other hand, studies by Gil and Margalit showed that the inferior turbinate is supplied by three arteries; the turbinate branch of sphenopalatine, anterior ethmoidal and lateral nasal (branch of facial) arteries. Accordingly they provide that the anteriorly based inferior turbinate flap made possible and successful by the anteriorly blood supply of inferior turbinate from anterior ethmoidal artery, rather than, other anteriorly located arteries[33] (Figure 2.6).

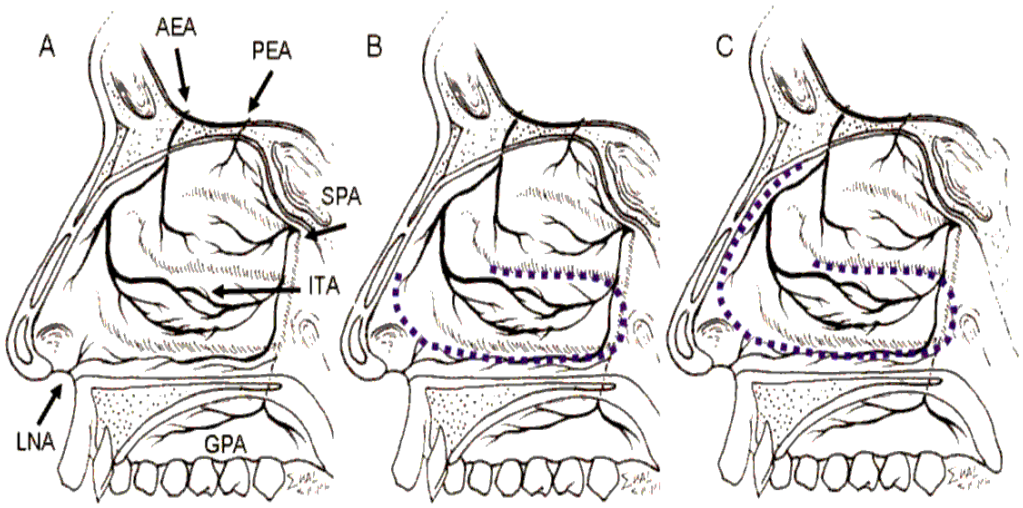

Figure 2.6. A. The blood supply of lateral nasal wall. B. and C. the design of the flap used. AEA, anterior ethmoidal artery. PEA, posterior ethmoidal artery. SPA, lateral branch of sphenopalatine artery. ITA, inferior turbinate artery. LNA, lateral nasal artery. GPA, greater palatine artery[33].

Furthermore, Gras-Cabrerizo *et al.* in their study for pedicle flaps have proved that the inferior turbinate artery terminations anastomose with palatine artery (branch of descending palatine) and branches that come from angular artery. In addition to the fact that the anastomosis which is present between the posterior lateral nasal artery and ethmoidal arteries in the lateral nasal wall[23].

Mustafa *et al*. investigated blood supply the inferior turbinate; using twenty formalin- fixed sagittally sectioned cadaveric heads. They found that the inferior turbinate receives its blood supply from inferior turbinate artery which is one of two terminal branches of posterior lateral nasal artery; the other terminal branch is the middle turbinate artery. In one specimen they found that the posterior lateral nasal artery trifurcate rather than bifurcate; giving two inferior turbinate arteries and one middle turbinate artery. The authors also investigated the type of ramification of the posterior lateral nasal artery. they showed that the artery either ramify close to the middle turbinate, i.e. in the upper half of the space between middle and inferior turbinates, in what they called 'proximal ramification', or the artery ramify close to the inferior turbinate, i.e. in the lower half of the space between the two turbinates, and they called this type as 'distal ramification'[34].

The course of inferior turbinate artery was in the submucosa in most of the cadavers, and in some cases it travelled in a deep sulcus on the lateral nasal wall. The artery was submucosal in all specimens just before entering the inferior turbinate. The inferior turbinate receives it blood supply form the inferior turbinate artery in 85% of specimens studied, while in the other 15% of specimens the artery is supported by additional branch from descending palatine artery. The later joined the inferior turbinate artery posteriorly above the inferior turbinate and anterior to the posterior attachment of inferior turbinate for about 4.5mm in average. There was no other additional blood supply to the inferior turbinate, they found. The inferior turbinate artery entered the turbinate in the posterior 1/3 of it, and then it divides into two branches run parallel to each other. The inferior concha was closely related to the artery through its course anteriorly toward the front of the turbinate.

They also found that, on contrary of previous studies, there was no bony canal through which the artery runs[34].

3. MATERIALS AND METHODS

3.1. preparations of specimens:

Forty formalin-fixed hemisected human heads were obtained from the laboratory of anatomy; Hacettepe University/ Faculty of medicine were used in the study.

First; the heads were cut in midsagital plane using electrical and/or hand saw. Then the specimens were fixed in 10% formalin till the dissection was done, which is usually after one week of fixation. The dissection was made using fine dissection tools and with the aid of dissecting microscope (Carl Zeiss Surgical GmbH, 73446 Oberkochen, Germany) (figures 3.1)

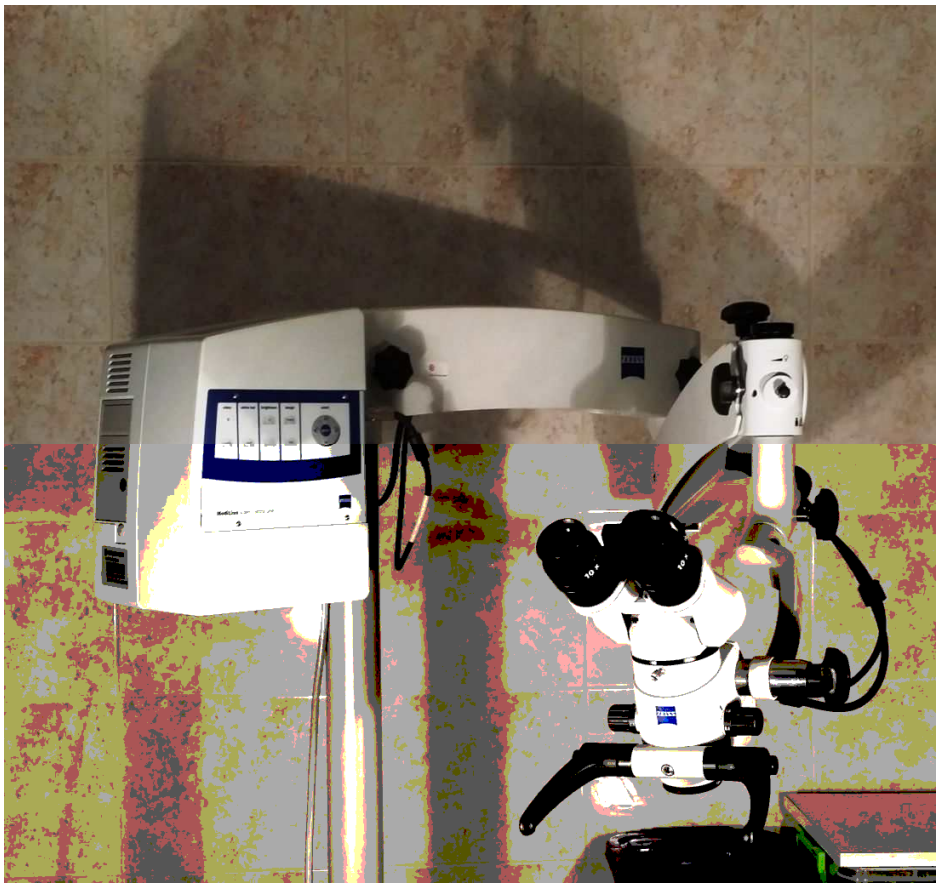

Figure 3.1. Carl Zeiss Surgical GmbH dissection microscope

The specimens were taken out from basin, washed out with tap water and cleaned from any debris in preparation for dissection. The dissection was done at anatomy laboratory under normal conditions (room temperature, lighting, and positioning). Then the specimens were positioned in a dissection tray with the lateral nasal wall side facing up toward the dissector. The lateral nasal wall was thoroughly inspected and examined for any deformity, variation, or pathology if present. After that the dissection of the nasal wall started.

3.2. Dissection methods:

Using a fine surgical scalpel and fine scissor, the sphenopalatine artery and its branches were identified and then injection of a dye was made to the artery, by syringe with dentine needle (G 30), to follow its course and its small ramifications. This procedure enable easier visualization and following of the arterial branches as these branches are too small and readily missed during routine dissection.

Then the branch of the sphenopalatine artery, posterior lateral nasal artery, was followed downward, the artery might gives the middle turbinate branch, which goes to the middle turbinate, then the artery continues downward as the inferior turbinate artery, which was identified and followed till it entered the inferior turbinate. After that the arterial course within the turbinate was explored, dissection continues anteriorly for the turbinate till its anterior end. The branches of inferior turbinate artery were traced forward where they anastomose with the branches of anterior ethmoidal or facial artery.

The ophthalmic artery was also identified in the cranial fossa as it branched off the internal carotid artery. Another dye injection was done to the ophthalmic artery, using intravenous cannula (24 G) as the artery enters the orbit to visualize the anterior and posterior ethmoidal arteries and their courses in the lateral nasal wall.

3.3. Measurements calculations:

Measurements were taken by using digital calibre and registered in a special table prepared for this study in order to do further statistical calculations. The images were captured for the artery in situ and the lateral nasal wall anatomy using digital camera. The magnifications were considered according to the microscope magnification power. As the images were taken through the eye piece of the microscope by the digital camera, the camera factor was not included. The measurements were done as follow:

The diameter of inferior turbinate artery was taken just before the entrance of the ITA to inferior turbinate, distance between the sites of entrance of inferior turbinate artery to the inferior concha and the posterior end of the concha, length of the ITA, distance between the ITA and choana, distance between ITA and auditory tube, distance between ITA and anterior nasal spine, inferior turbinate length, and the number of branches of ITA in the inferior turbinate. All the measurements were taken in millimetres. These measurements were arranged in a table and the average was taken and the standard deviation.

Other measurements were taken regarding the location of the sphenopalatine foramen, whether it lies in the superior meatus, middle meatus or in the transitional zone between them. The site of the division of sphenopalatine artery was investigated in relation to the sphenopalatine foramen, whether it divides before or at the foramen, or it enter the nasal cavity as single trunk and then divides inside the nasal cavity into its terminal branches. Other measurements was done to investigate the presence of a

branch from the sphenopalatine artery to the superior turbinate , or if the branch to the superior turbinate come from the nasoseptal artery.

4. RESULTS

4.1. Sphenopalatine artery:

The sphenopalatine artery (internal maxillary artery), one of the terminal branches of external carotid artery, entered the nasal cavity through the lateral wall at the sphenopalatine foramen coming from the pterygopalatine fossa. It was identified, or its branches, in all the dissected specimens. Although small accessory foramena were found in three cases which were located just below the sphenopalatine foramen, this foramen admits small artery that courses to the middle turbinate (in one case), whereas the artery anastomosed with the inferior turbinate artery in the other two cases (figure 4.1.).

The position of the sphenopalatine foramen in the lateral nasal wall was investigated and it was found to be located at the posterior lower end of the superior meatus and just above the posterior end of middle turbinate in 35 case (87.5 %), and lateral to the posterior end of middle turbinate in 5 (12.5 %) of cases (table 4.1).

Table 4.1. Shows location of SPF, site of division of SPA, and presence of superior turbinate branch of totally 40 cases.

Location of SPF			Site of division of SPA		Branch of SPA to superior turbinate		
Sup. meatus	Transitional zone	Middle meatus	Outside nasal cavity or In the foramen	Inside nasal cavity	Present	Absent	Others (from NSA)
0	35	5	36	4	15		25

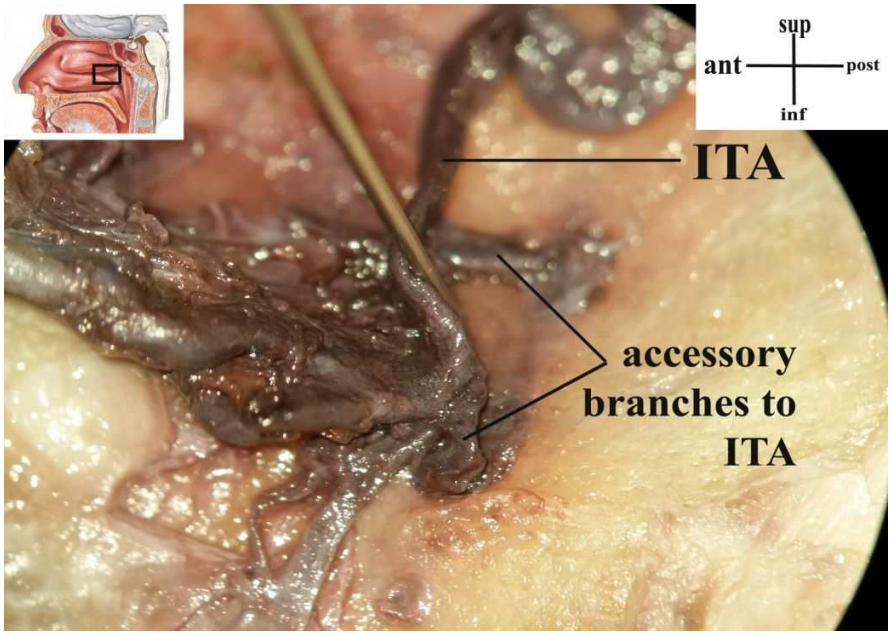

Figure 4.1. Accessory foramen below the sphenopalatine foramen admits artery to the inferior turbinate (magnification 16 X).

4.2. Branching pattern of sphenopalatine artery:

The artery showed two types of branching pattern according to the location of division, it was found to divide into its branches before or at the sphenopalatine foramen in 36 case (90 %) (figure 4.2) and inside the nasal cavity in four (10 %) of cases (figure 4.3. and table 4.1). The terminal branches were posterior lateral nasal (PLNA), nasoseptal (NSA) and superior turbinate artery (STA)). In 25 cases the superior turbinate branch was found to be a branch of nasoseptal artery, i.e. in that condition the sphenopalatine artery gives two terminal branches PLNA and NSA.

The nasoseptal artery, as it branched from the sphenopalatine artery, it passes medially on the sloping anterior surface of the body of the sphenoid bone, where the sphenoid sinus usually located, reaching the nasal septum from behind to

participate in the blood supply of the septum. The posterior lateral nasal artery courses downward in the mucosa of the lateral nasal wall.

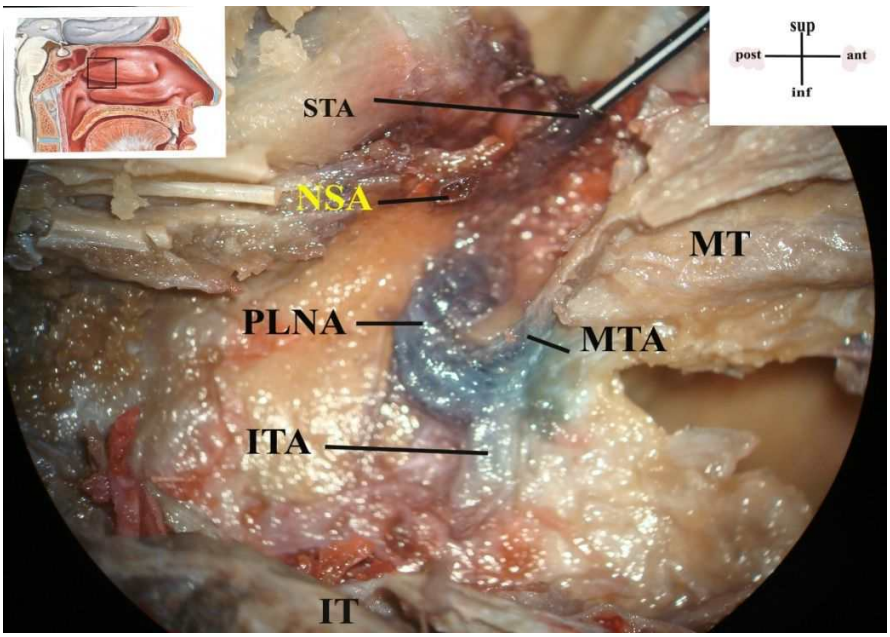

Figure 4.2. SPA divided into three branches; septal artery, artery to superior turbinate, and PLAN (magnification 10 X).

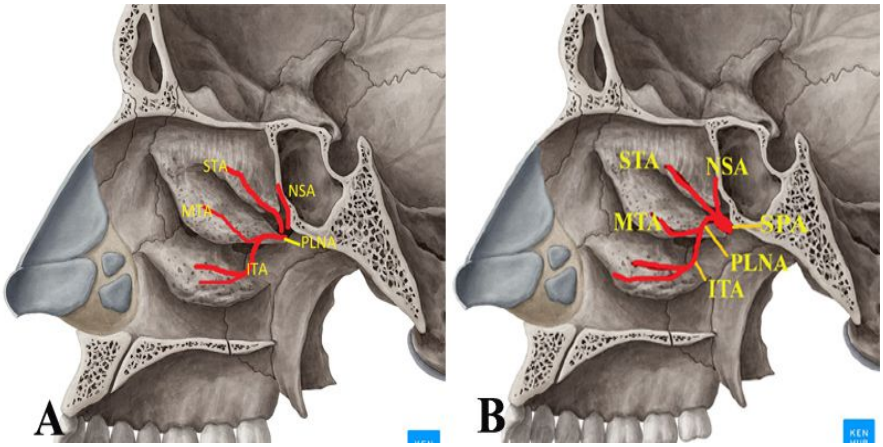

Figure 4.3. diagrammatic view of branching pattern of SPA. A. Branching before entering the nasal cavity. B. branching inside the nasal cavity.

4.3. The ethmoidal arteries:

The posterior and anterior ethmoidal arteries are branches of ophthalmic artery which given off after the later enters and courses the orbit. These arteries supply the ethmoidal air cells and make a course in the anterior cranial fossa then give nasal branches which descend to the nasal cavity through the cribriform plate of ethmoid bone. After entering the nasal cavity, these arteries were identified. They enter the cavity separately with a distance 5-7 mm between them. The anterior ethmoidal artery was followed when identified and it was found to give small branch to the superior turbinate, which approaches it from above and front to participate in its blood supply. The artery then continues downward on the lateral nasal wall anterior to the turbinates. It was found that the terminal branches of the anterior ethmoidal artery anastomose with the terminals of inferior turbinate artery in front of the anterior end of inferior turbinate; although in some cases the anastomosis was found on above level near the middle turbinate(figure 4.19 a, and figure 4.20). The branches of ethmoidal arteries were found to be too small in relation with that of the sphenopalatine arteries, an evidence suggesting the dominance arterial supply.

4.4. Blood supply of superior turbinate:

The superior turbinate consists of a bony core, the superior concha, which is projected from the medial wall of ethmoidal labyrinth, and a soft tissue covering made of the nasal lining mucosa. Superior turbinate was found to be supplied by a branch arise from the nasoseptal artery (figure 4.4), while in other cases the superior turbinate branch given directly from the sphenopalatine artery at /or immediately after the artery exits the sphenopalatine foramen (figure 4.5 and table 4.1). The artery runs upward in the mucosa of the lateral nasal wall within the superior meatus approaching the posterior end of the superior turbinate from

below. In addition to that, the superior turbinate take further blood supply from posterior and anterior ethmoidal arteries, these arteries encroaches to the nasal cavity from the roof. The branch which came from the anterior ethmoidal artery descends downward on the lateral nasal wall and approaching the superior turbinate from its anterior end (figure 4.6).

The branch of sphenopalatine artery that supply the superior turbinate was found to be smaller in diameter than the others that supply the middle and inferior turbinate, this make sense because the differences in the sizes of the turbinates which need different arterial blood flow. Nevertheless, the branch from SPA that supply the superior turbinate still larger than that of the ethmoidal arteries to the turbinate; giving a clue of the dominant blood supply to it.

However, the superior turbinate has dual blood supply from branches of both external and internal carotid arteries.

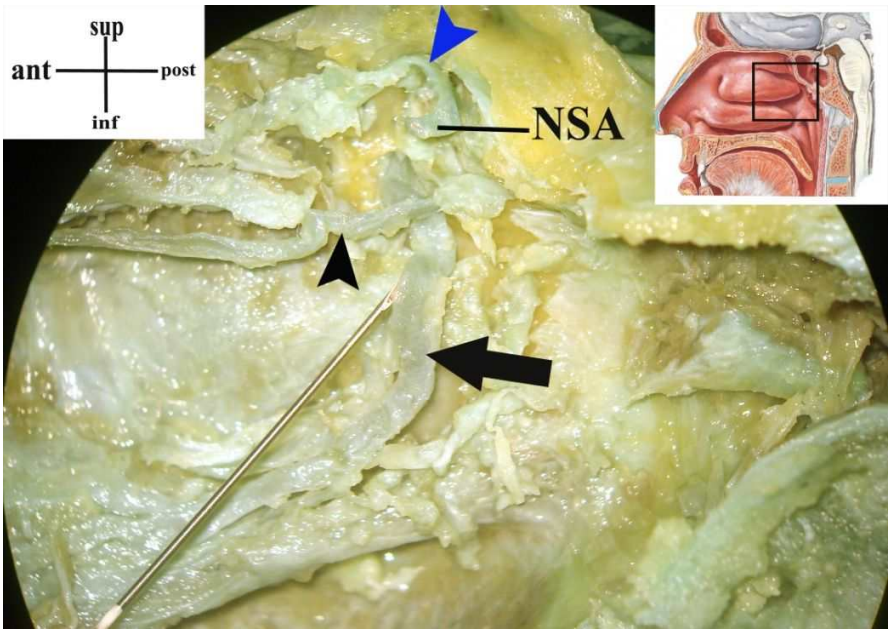

Figure 4.4. Superior turbinate artery (blue arrow head) arises from nasoseptal artery. MTA (black arrow head). Inferior turbinate artery (black arrow). (Magnification 10X)

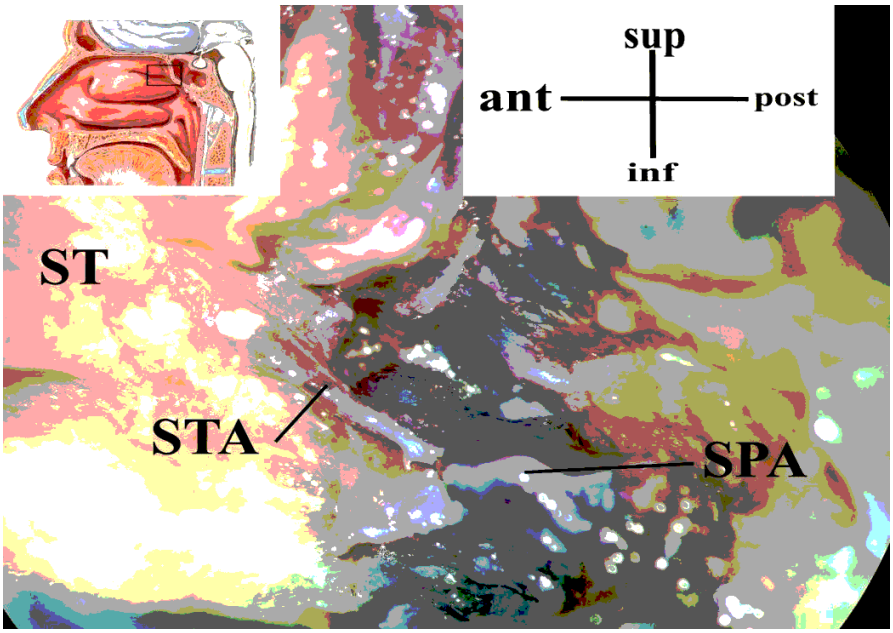

Figure 4.5. Superior turbinate artery arise from SPA. (magnification 25X)

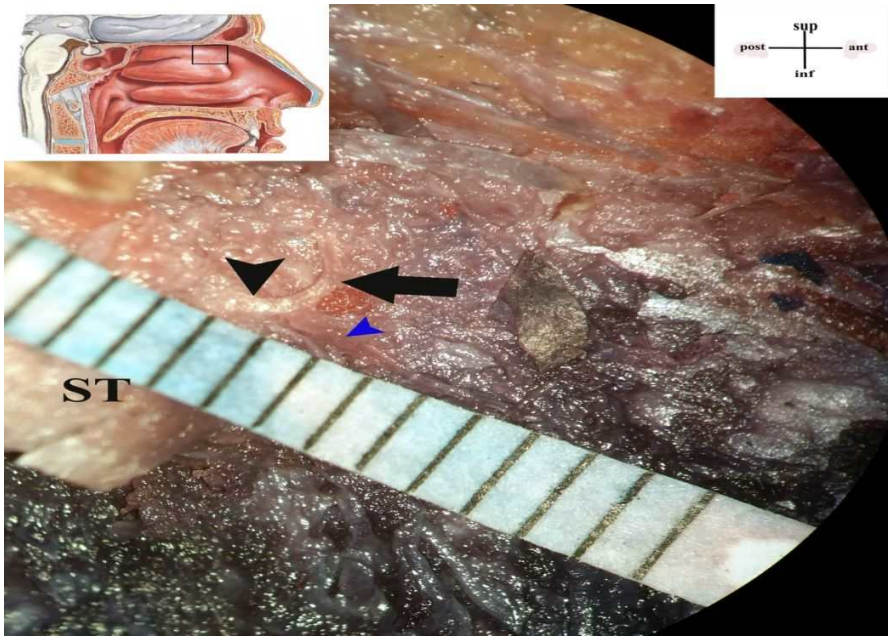

Figure 4.6. Anterior ethmoidal artery (arrow) gives a branch to superior turbinate (black arrow head) and another branch which descend on the lateral nasal wall (blue arrow head). (magnification 25X).

4.5. Blood supply of middle turbinate:

The middle turbinate artery branched off the posterior lateral nasal artery at a level inferior to the attachment of middle concha. It was found that the artery runs in one of two courses. The first one, which is the commonly found in the study, is the horizontal course of the artery where it passes after its emergence from the posterior lateral nasal artery, in what we called high origin, in which the artery approaches the middle turbinate from its posterior end and continue forward within the turbinate (figure 4.7). While in the second course, the middle turbinate artery found to originate from the PLNA at a low level and take an oblique upward path, in cases we called it lower origin of the artery, crossing the middle meatus and approaching the middle turbinate from below in its posterior one-third. In the later cases it was found that the artery may gives the antral branch (figure 4.8). In one case, we found that the middle turbinate has been supplied by double branches that both came from the posterior lateral nasal artery (figure 4.9). Furthermore, the middle turbinate was supplied by a second branch that comes from SPA separately, as discovered in one case (figure 4.10).

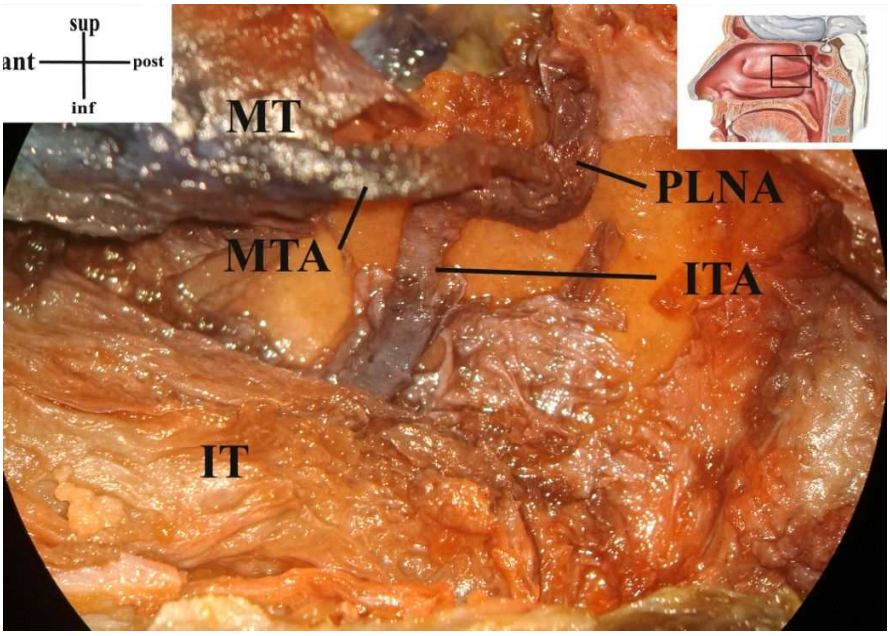

Figure 4.7. Middle turbinate artery arises from PLNA high up and approaches the turbinate from behind. (Magnification 10X)

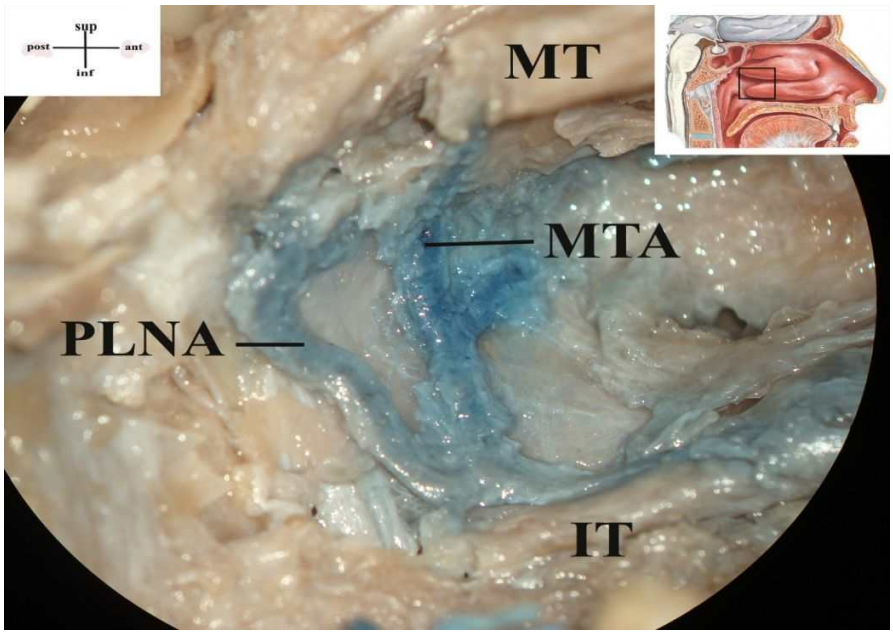

Figure 4.8. Middle turbinate artery arises from PLNA at a low level and passes up to reach the turbinate. (magnification 16X)

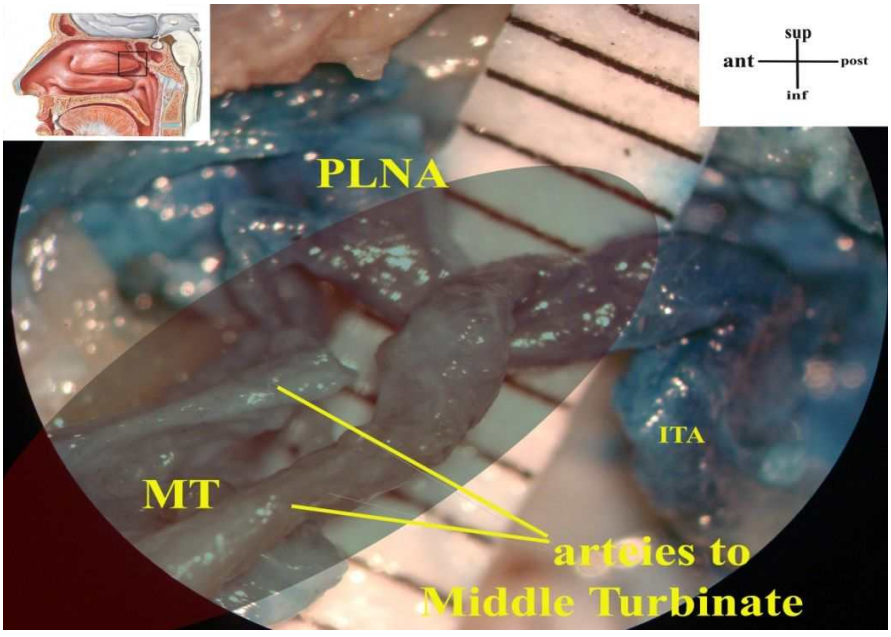

Figure 4.9. Shows double branches from PLNA to middle turbinate. The shadow area represents removed middle turbinate. (magnification 16X)

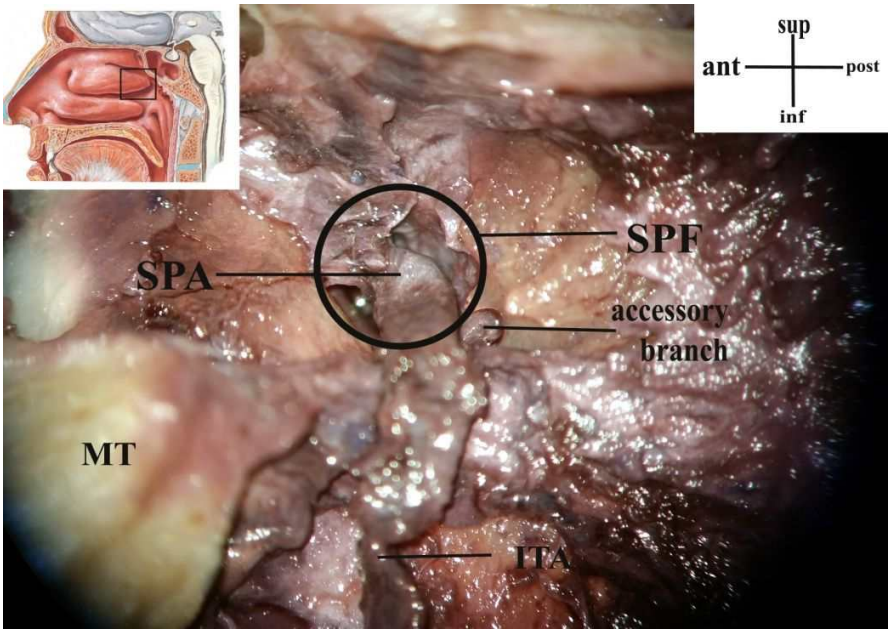

Figure 4.10. Middle turbinate receives accessory branch from SPA in addition to branch from PLNA. (magnification 16X)

4.6. Blood supply of inferior turbinate:

The inferior turbinate was examined in the dissected specimens and its length was taken, it was found that the length varied from 32.89-52.46 mm (average 45.81±4.01 mm). Its thickness and shape showed slight difference also.

The posterior lateral nasal artery, one of the terminal branches of sphenopalatine artery, continues as inferior turbinate artery after it gives off the middle turbinate branch. The artery passes downward on the lateral wall of nasal cavity lateral to the middle turbinate, that's to say it is under covered by the posterior end of the middle turbinate, and about 7 mm from its posterior end. It was found that the artery either made a slight curve in its downward course passing anteriorly for a short distance then it continues down to reach the inferior turbinate from above, or it passes steeply downward to its destination(figure 4.11. a. and b). In some cases the artery showed a marked tortuous course (figure 4.12).

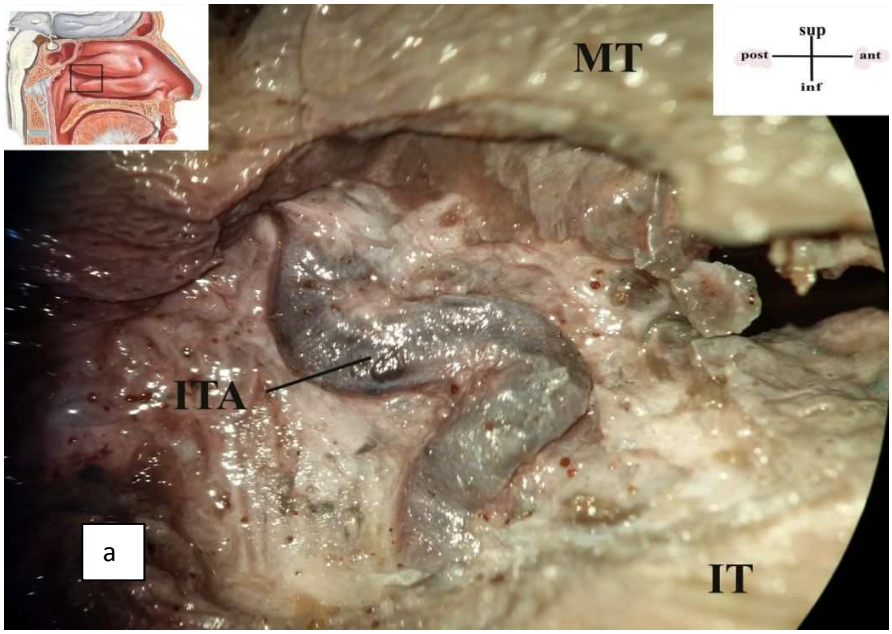

Figure 4.11. a. Shows variation of the courses of ITA. when the artery make a curved path. (magnification 16X)

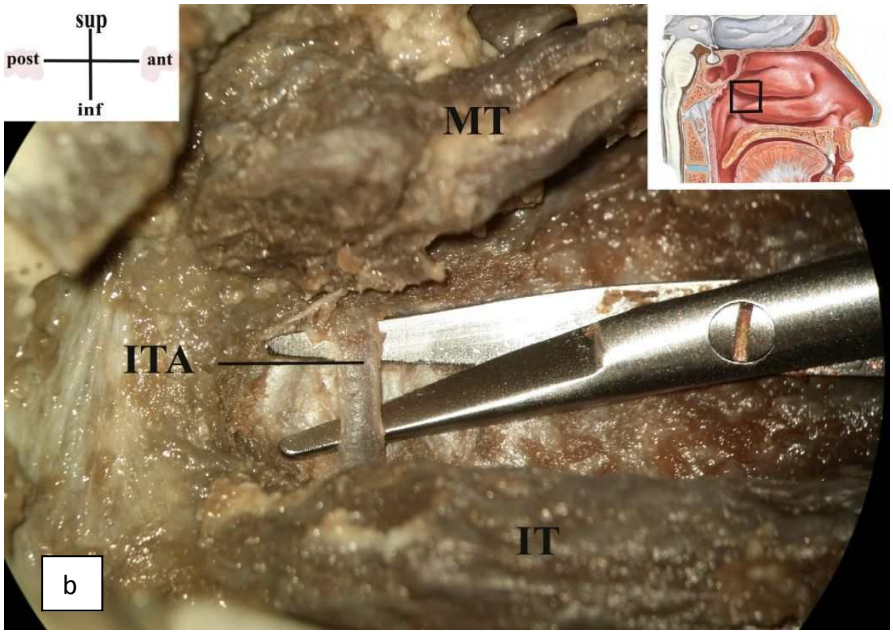

Figure 4.11. b . Shows variation of the courses of ITA. Steep downward course. (magnification 10X)

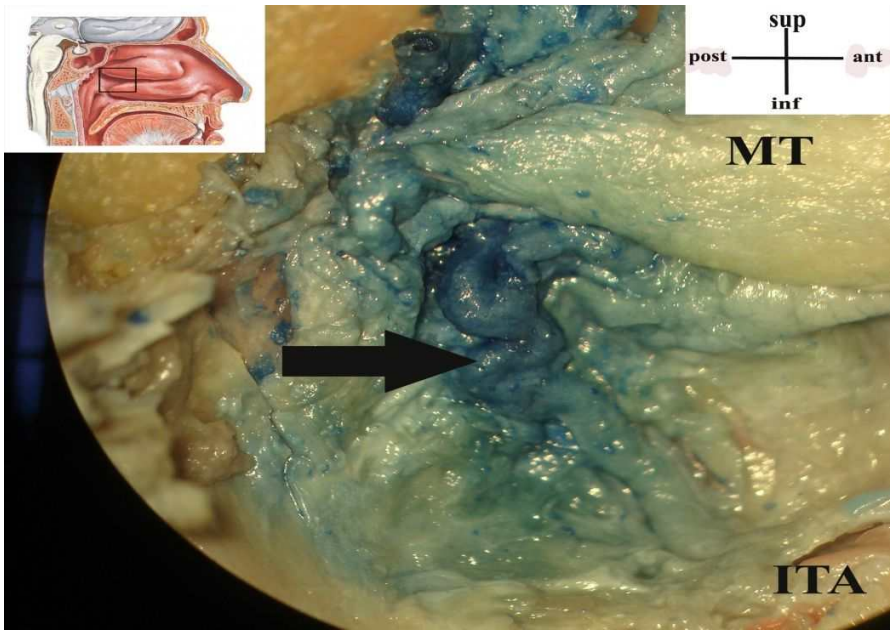

Figure 4.12. Tortuous course of ITA. (magnification 10X)

The diameter of the artery was measured and it was found to be 1.23-2.06 mm (average 1.452 ± 0.17 mm) table 4.2. The measurements were taken just before the entrance of the artery to the inferior turbinate. The length of the artery was also measured which was varied from 5.04-12.46 mm (average 9.057 ± 1.67 mm). This distance was taken for the artery after the middle turbinate artery has been giving off till the site of entrance to the inferior turbinate, that's explain the big variation in the length of the artery measurements.

The ITA enters the inferior turbinate from above and at a distance from its posterior end, i.e. not enters from its posterior tip, this distance was measured and it is found to vary from 4.74-12.02 mm (average 7.87 ± 1.52mm). The artery enters the inferior turbinate at a right angle to the long axis of inferior turbinate in some specimens, where as in the rest of cases it has a mild oblique course. During its path

on the lateral nasal wall, the artery was found to make a groove in the bony wall in two cases, but not tunnelling the wall (figure 4.13).

While approaching the inferior turbinate, the artery gave an antral branch that course forward and upward (figure 4.14), while in some cases the antral branch runs in a horizontal path shortly after the middle turbinate artery was given off (figure 4.15). In few cases the antral branch was given from the middle turbinate artery (as mentioned before).

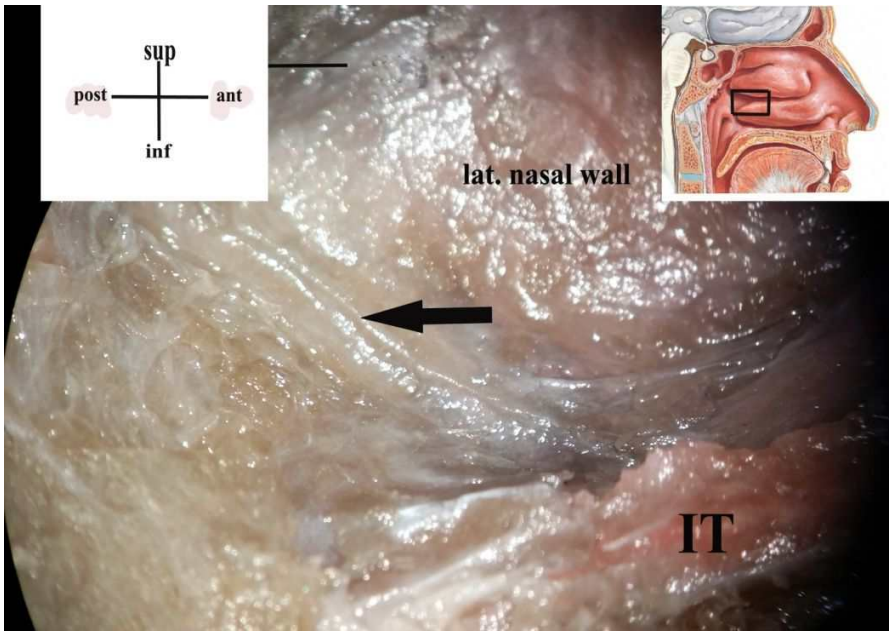

Figure 4.13. The ITA makes a tunnel in the lateral nasal wall. (magnification 16X)

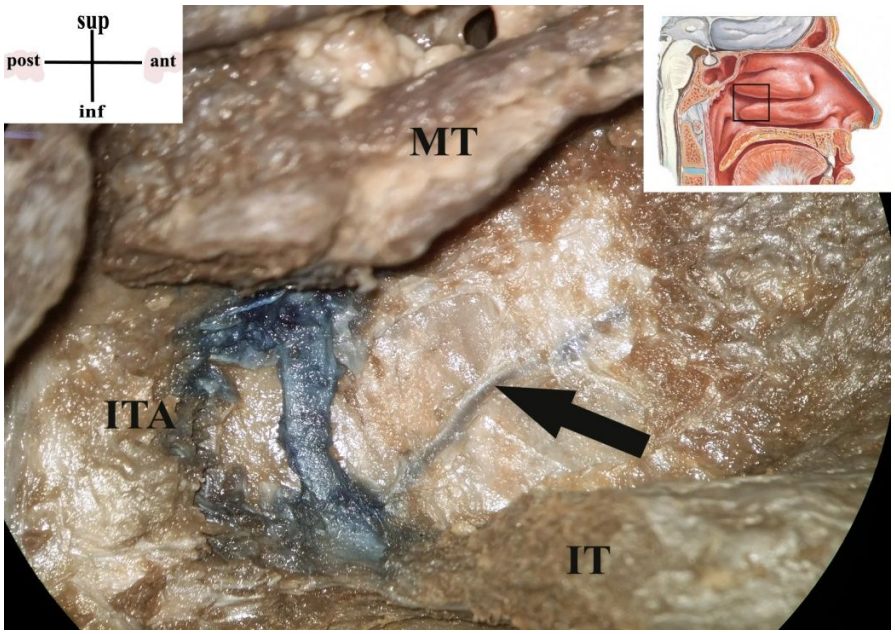

Figure 4.14. The antral branch (arrow) arises from ITA before the later enters the inferior turbinate. (magnification 10X)

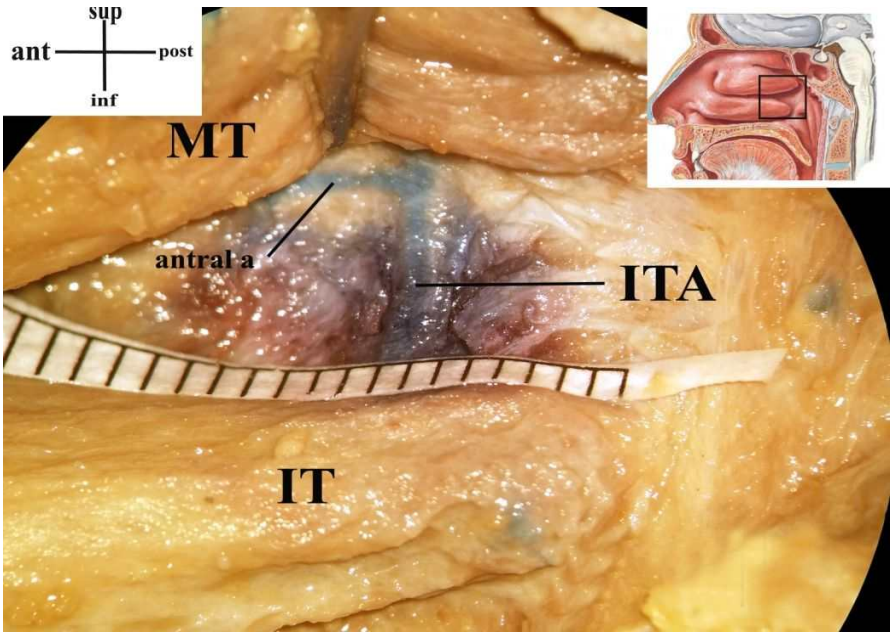

Figure 4.15. Antral branch arises high from the ITA. (magnification 10X)

On reaching the inferior turbinate, the inferior turbinate artery divides into two in 36 cases (90%) or three branches in 4 (10%) of cases. These branches found to be differing in diameter with one of them is larger than the others (figure 4.16 a and b). In cases of bifurcation of the inferior turbinate artery, one of the branches passes inferoposteriorly for short distance before it changes its course anteriorly, the other branch passes forward from the site of division and continue in that direction. In other cases, both the two branches of the ITA run anteriorly with one of them superior to the other. The superior branch usually lies closer to the lateral attachment of the turbinate, i.e. closer to the lateral nasal wall, while the inferior one tends to be more medially located in the mid of the turbinate or even closer to its medial margin. The diameter of the branches was found to decrease as they proceed forward.

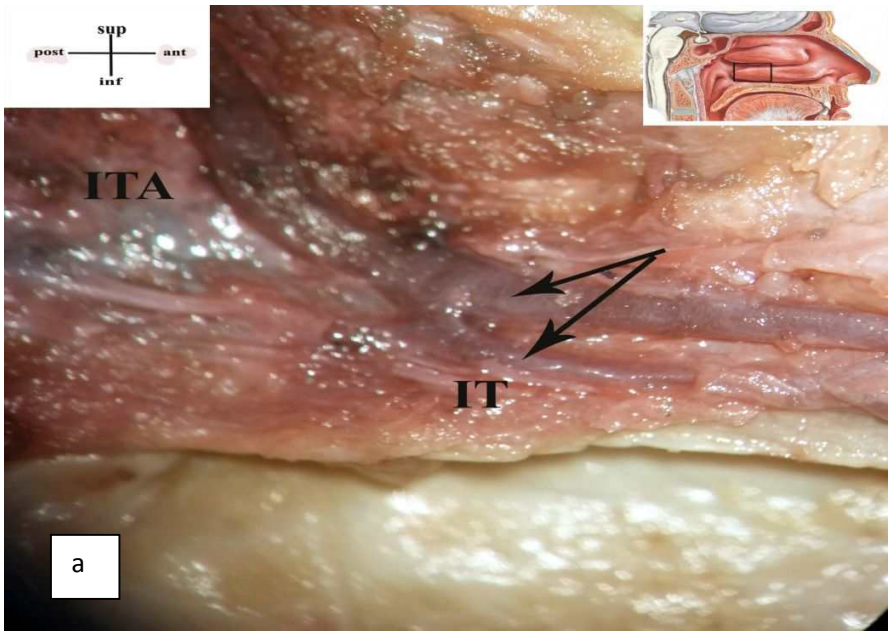

Figure 4.16. a. Branching pattern of ITA. bifurcation of ITA.

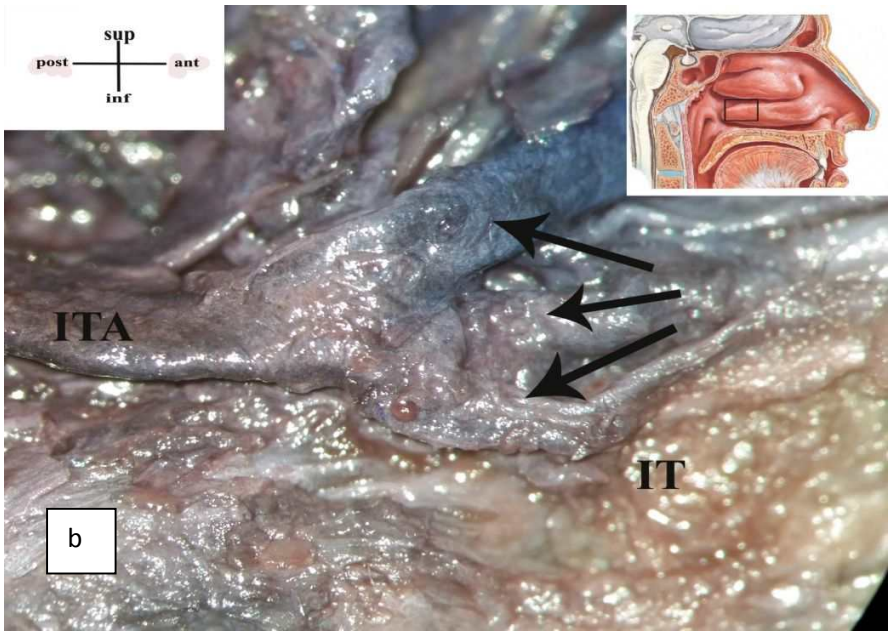

Figure 4.16. b. Branching pattern of ITA. trifurcation of ITA. (magnification 16X)

Located within the inferior turbinate, the branches run in bony canals through part of their courses. The roofs of the canals were made of thin lamina of bone of the inferior concha. These bony canals have to been opened through the dissection procedure to follow the arteries in the inferior turbinate. Within these canals, a fascial coat was found to wrap the arteries to which it is firmly attached. The branches communicate with each other and send small arteries reaching the surface of the turbinate (figure 4.17 a and b).

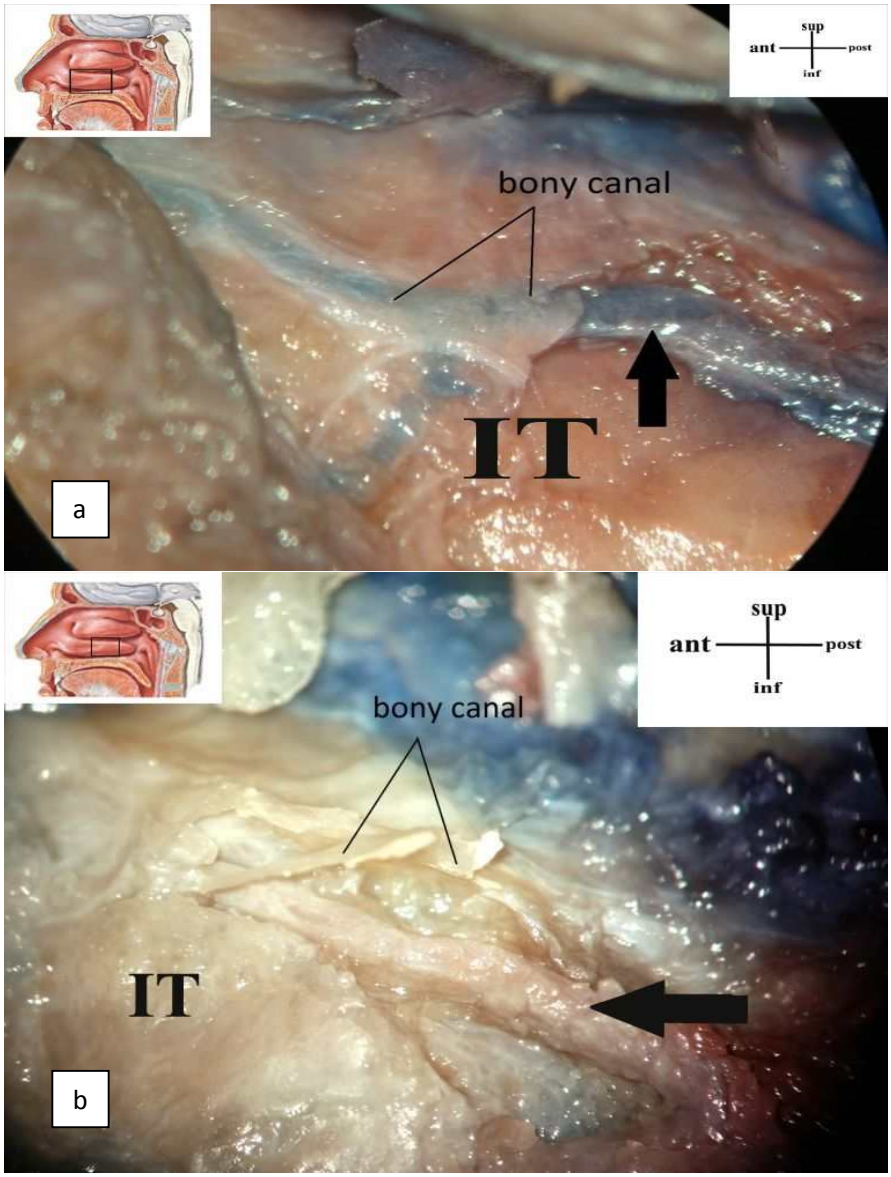

Figure 4.17. Branches of ITA (arrows) run in bony canals which partially opened for demonstration. (magnification 16X)

Nevertheless, in one case, the inferior turbinate found to have an additional blood supply from accessory branch that came from descending palatine artery, this branch enters the nasal cavity through its lateral wall via accessory foramen located

above the inferior turbinate and unite with the inferior turbinate artery that come from the PLNA and continue as a single artery to the turbinate (figure 4.1).

Out of the forty specimens dissected, in just one case, we found that the inferior turbinate artery did not come from the usual way which is the PLNA, but it came solely from a branch of the descending palatine artery through a separate foramen in the lateral nasal wall which admits that branch. This artery passes downward on the nasal wall reaching the inferior turbinate which it supply (figure 4.18).

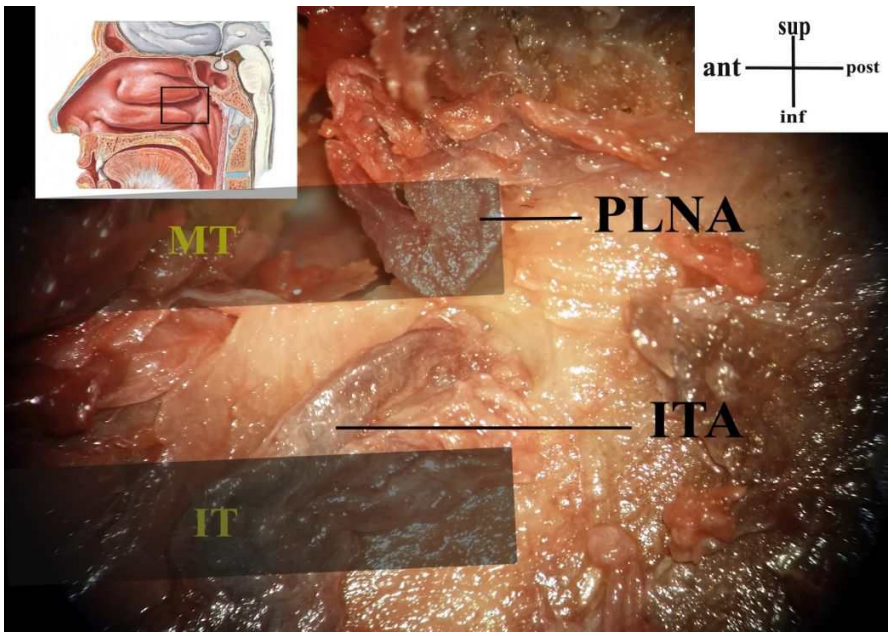

Figure 4.18. The inferior turbinate supplied by branch arise from descending palatine artery which make access to the nasal cavity through an accessory foramen in the lateral wall. Shadow areas represent removed MT and IT (magnification 16X)

On following the terminal branches of the inferior turbinate artery in the turbinate; they obviously become smaller in size. In front of the anterior end of the inferior turbinate, it was found that there is a sort of anastomosis between the terminal branches of inferior turbinate and branches which come from the anterior ethmoidal artery, that descend from above on the lateral wall, and branches from

the facial artery which encroaches from below through the nares (figure 4.19 a and b). The site of the anastomosis found to located few millimetres anterior to inferior turbinate, or even at a level higher up anterior to middle turbinate when the terminal branches of inferior turbinate artery sneaks upward from the inferior turbinate (figure 4.20).

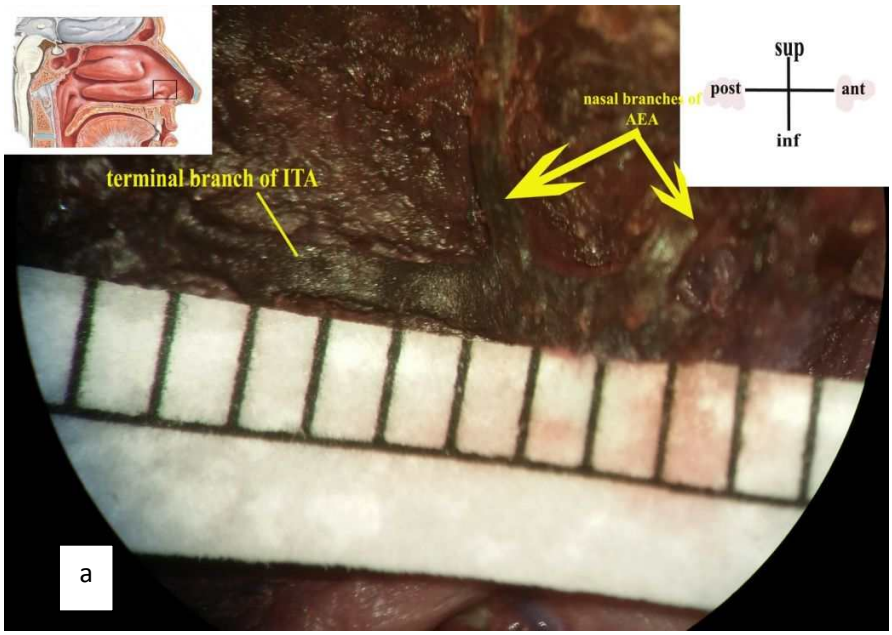

Figure 4.19. a. Anastomosis located anterior to inferior turbinate between terminal branch of ITA and nasal branch of anterior ethmoidal artery. (magnification 25X)

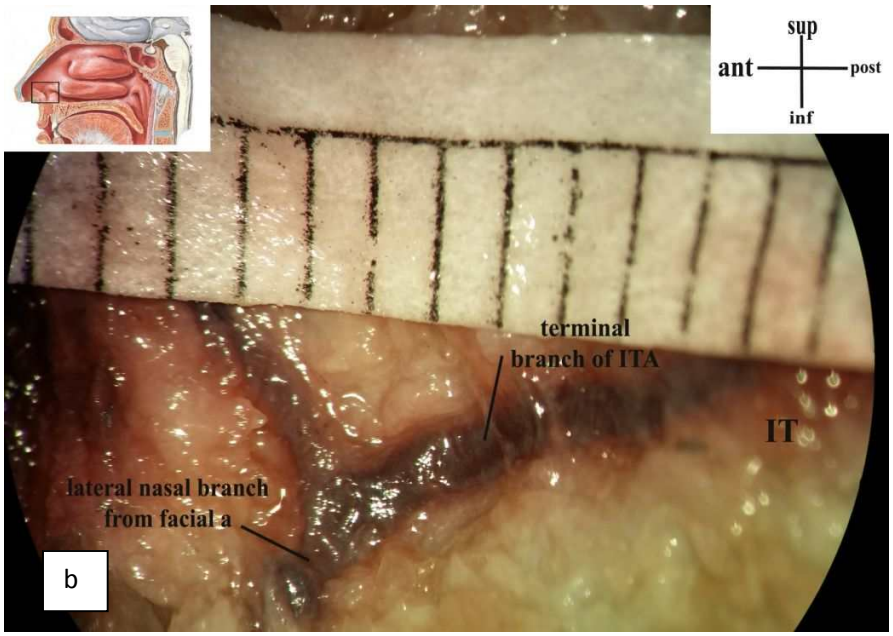

Figure 4.19. b. Anastomosis located anterior to inferior turbinate between ITA and lateral nasal branch comes from facial artery. (magnification 25X)

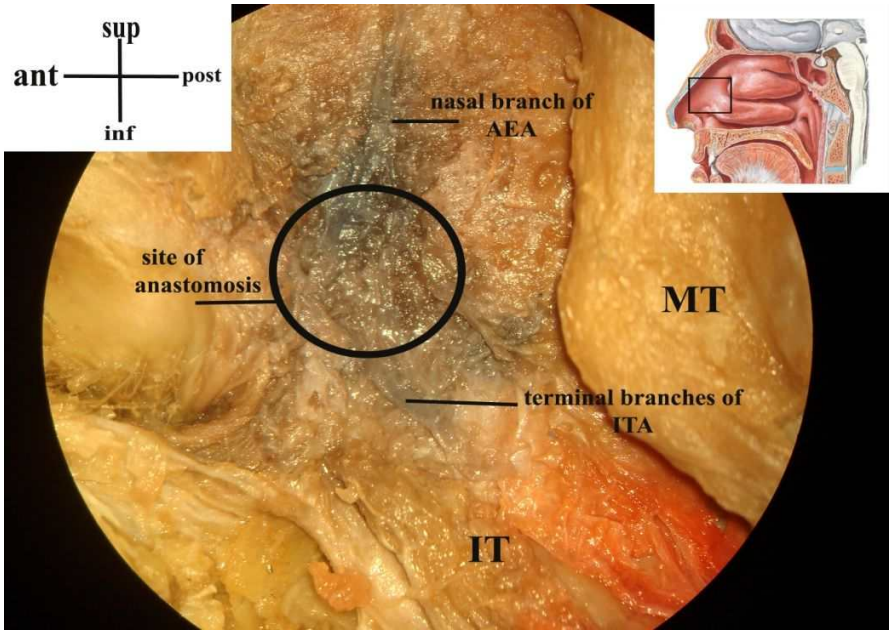

Figure 4.20. Anastomosis between anterior ethmoidal artery branches and ITA anterior to middle turbinate. (magnification 10X)

Table 4.2. Shows measurments of diameter of ITA and other statistics related. Measurments in mm.

Average diameter of ITA in mm	Distance from post. end of IT	Average length of ITA	Distance from choana	Distance from auditory tube	Distance between entrance of ITA to IT From SPF	Average of inferior turbinate length	Average distance from ant. nasal spine
1.452 ± 0.172	7.879 ± 1.529	9.057± 1.674	11.212 ± 2.008	14.683 ± 1.520	12.716 ± 1.448	45.813 ± 3.257	48.969 ± 3.903

5. DISCUSSION

In recent years, endoscopic surgeries become the workhorse for the treatments of skull base and paranasal diseases. The accesses to the skull through the expanded endonasal approach become widely used to resect extradural and intradural tumours, in addition to the ability to expose the intracranial fields from frontal sinus to cervical spines. The limitation of such procedures is the large dural defects which need adequate reconstructions to prevent cerebrospinal fluid leaks. Hence, the need for flap reconstructions arises. The endonasal mucosa was chosen as a source of flaps to reconstruct skull base defects. Different techniques were developed based on the feeding blood of the flap choice, the size of the flap, and its applicability. Some surgeons used posteriorly pedicle flap, while others used the anteriorly pedicle flap depending on the blood supply of that flap and to ensure its vitality. For that reason, an adequate understanding of the blood supply of the lateral nasal wall play a key role in the success of such flaps[27, 33].

In addition to all of the above, the commonity of nasal bleeding (epistaxis) encountered by the otolaryngologists and the way of its managements which sometimes need surgical interventions, furthermore, the other common condition the otolaryngologists faced which is the nasal obstructions due to inferior turbinate hypertrophy that need surgical reductions, such operation which may encounter intra- or postoperative haemorrhage. All these conditions made the knowledge of the detailed blood supply of nasal wall of great importance to achieve successful managements of the mentioned clinical conditions and decrease further complications[34].

Nowadays, a great deal of interest was paid for a good understanding of the blood supply of the nasal cavity, the main arterial supply, and the minors or additional contributors, in respect to their courses and the occurrence of variations.

Unfortunately, the anatomical textbooks did not describe the detailed blood supply of the nasal cavity, they just mention the main arteries which participate in it, with further description of the anastomosis in the nasal septum '' Kiesselbach's plexus'' as it is the common site of nasal bleeding. Most of the detailed anatomy of the blood vessels of the nasal cavity were studied by various researchers and published in articles or even in surgical books related to otolaryngology and cranial surgery.

In the present study, we tried to get detailed anatomical information about the blood supply of the lateral nasal wall and, especially, the inferior turbinate. During dissection and examination of the lateral nasal wall, the sphenopalatine foramen was identified and its location was at the posterior end of superior meatus just above the middle concha in 87.5% of cases, that's to say it lies at the transitional area between the superior and middle meatus. In 12.5% it was found at a lower level just lateral to the middle turbinate. Previous studies concerning the location of sphenopalatine foramen conducted by Wareing *et al.* they classify the position of SPF into three classes; class I (35%) where the SPF purely located in the superior meatus, class II (56%) the SPF opens at the transition of middle and superior meatus, while in class III (9%) it was two separate openings on either sides of ethmoidal crest[32]. Furthermore, Prades *et al.* and Midilli *et al.* in their study on dried skull and sagittally sectioned cadavers, respectively, and Herrera Tolosana *et al* found that the most frequent incidence of SPF location was at the transition of middle and superior meatus[29, 31, 36]. In accordance of these previous works, we found that the incidence of the site of the SPF was located between the superior and middle meatus, and to lesser extend at a lower level. We did not found class I type of SPF in the dissected specimens. Massick and Tobin mentioned that the SPA entered through the SPF which located at the posterior end of superior meatus[22], while Wormald stated that the location of the foramen was at the posterior end of middle turbinate[37].

The sphenopalatine artery which is one of the terminal branches of maxillary artery (internal maxillary artery) enters or its branches the nasal cavity through the sphenopalatine foramen. The site of division of the artery into its branches was found to be before or at the foramen in majority of cases (90%), while it was inside the nasal cavity in few (10%) cases. In the former condition, the sphenopalatine artery divides into two constant branches; the posterior lateral nasal and nasoseptal (posterior septal) arteries, in addition to the artery that goes to the superior turbinate which is found in some cases (37.5%). There are may be additional branches that supply the middle turbinate or inferior turbinate which arise separately from the SPA apart from the other constant branches. These arteries entered the nasal cavity separately and take their courses toward their destinations. In the other condition, the SPA enters the nasal cavity as a single trunk then it divides inside into its terminal branches which are the same as the above, although variations were not uncommon. Our finding were in consistent with works of Lee *et al.* who stated that the SPA divides into two to four branches before exiting the sphenopalatine foramen in majority of specimens they dissected. Nevertheless, Midilli *et al.* support such findings in their study, they showed that the branching of the SPA were within the foramen in 80% of cases[29]. As well as Babin *et al.* on their work on fresh cadavers found the same results[27]. While Gras-Cabrerizo *et al.* mentioned that the SPA found as single trunk inside the nasal cavity in 63% of cases which they studied[23]. Burnham describes the SPA branching on entering the nasal cavity where it breaks up into inferior turbinate, middle turbinate and nasopalatine arteries[19]. Wormald also stated that the SPA divided into its branches immediately after exiting from the foramen[37].

It is clear that the interest in the anatomy of the nasal cavity become increased over the last years, this become obvious through the change in the names of the branches of the main arterial supply of the nasal cavity. For example, the nasopalatine artery[19, 27], which is one of the terminal branches of sphenopalatine

artery, that supply the nasal septum in addition to superior turbinate, its name changed to nasoseptal artery later on[28, 31, 38], and nowadays this artery is called posterior septal artery and the nasopalatine name is confined to the terminal branch of it that courses in the nasal septum[4, 19]. Furthermore, the previous nomenclature of the branches of SPA was markedly changes. Tami describes the SPA branches as descending palatine artery, which give blood supply to the inferior turbinate, and posterior septal artery which supply the nasal septum[25]. Wormald mention the branches of SPA as posterior nasal artery and branches to middle and inferior turbinate, without naming the posterior lateral nasal artery[37], while Massick and Tobin noted to the branches of SPA as nasopalatine and posterior superior branch, the later supply the middle and inferior turbinates[22].

The recent terminology of the branches of SPA was: posterior lateral nasal and posterior septal arteries, although some researchers still use the old names.

The superior turbinate, the smallest turbinate in normal conditions – apart from supreme turbinate when it present- was found to receive its blood supply from the branch to superior turbinate. This artery has different sources of origin; either it arise from the nasoseptal branch, which is the common condition, or it branched off the sphenopalatine artery directly as the most superior branch of this artery. The artery takes its course upward on the lateral nasal wall, in the superior meatus, approaching the superior turbinate from below the posterior end of it. Within the turbinate, it passes forward toward the anterior end of the turbinate. The anterior and posterior ethmoidal arteries participate in the blood supply of the turbinate, approaching from above. The anterior ethmoidal artery descends from the roof of the nasal cavity through the cribriform plate of ethmoid and send branch that supply the superior turbinate, then the artery continues down on the lateral nasal wall in front of the superior and middle turbinates to take part in the anastomosis anterior to the inferior turbinate with the terminal branches of the inferior turbinate and the

lateral nasal branch from facial arteries[4]. It was noted that ethmoidal arteries were too small in comparison with the branch that arise from the SPA, directly or indirectly, giving a clue to the main source of the blood supply. Previous studies conducted by Burnham describe the superior turbinate artery which given off the nasopalatine artery and passes to the turbinate anastomosing with ethmoidal arteries[19]. Babin *et al.* showed the superior turbinate supplied by an artery they call it superior nasal artery, this come from the nasopalatine branch in 60% of cases[27], while Zhang *et al.* demonstrated the presence of such artery but in fewer incidences than the others (38%)[21]. Midilli *et al.* also presented the superior turbinate artery in low ratio of the specimens they studied[29]. While Prades *et al.* did not mention about the superior turbinate artery in their study[31].

On the other hand, most of the otolaryngological textbooks regarded the superior turbinate as the territory of ethmoidal arteries irrigation. These textbooks ignored the participation of the sphenopalatine branches in the supply of the superior turbinate[22, 25, 26], while some otolaryngological books mentioned the role SPA in supplying the superior turbinate via branch that came from posterior nasal artery[37].

The middle turbinate, the middle of the three turbinate in size, found to be formed by a bony core and a covering mucosa. The middle turbinate become so important due to its position which may interfere with the endoscopic sinus surgical techniques, especially when its size is large enough to close the endoscopic view or when there is anomalies or pathologies involving the turbinate which need resection to proceed in the surgeries. Furthermore, the evolution of mucosal flaps which used the middle turbinate flaps to close defects in skull base, brought more interest about this turbinate and its blood supply. In the present study, the posterior end of the middle turbinate was found to cover the sphenopalatine foramen in about 11% of cases. The PLNA emerges from the SPF and passes downward lateral to the posterior

end of the turbinate. Padgham and Vaughan-Jones describe the same relation of PLNA to the posterior end of middle turbinate[20].

At a lower level, the artery to the middle turbinate arises from the PLNA. In most of cases, the middle turbinate artery takes a horizontal course forward at a level below the attachment of the middle concha, entering the turbinate from its posterior end. Burnham describes the middle turbinate artery course as on the lower border of the bone and enters a bony canal in the middle and posterior thirds junction[19]. While Berger *et al.* in their histological study of middle turbinate found the artery lies in the deep layer of lamina propria of the turbinate, not in bony canals[39]. We did not find in our work canals in the middle turbinate for the artery.

In other cases we found the middle turbinate artery arise at a lower level from the PLNA and takes an oblique course upward in the middle meatus toward the middle turbinate, entering its posterior third and continue forward. Mustafa *et al.* mentioned such low origin of the middle turbinate artery from the PLNA in 5% of cases they studied, but without details about the course of it. The middle turbinate artery was found to be the main blood supply of the turbinate, it was either single branch which arises from PLNA, or there is more than one branch that supply the turbinate comes from SPA directly or from PLNA too [34]. Prades *et al.* and Lee *et al.* mentioned collateral branch arise from the stem of the SPA at its exit from the SPF supplying the middle turbinate[28, 31]. It is worthy to note that the entrance of these arteries to the turbinate were from its posterior end, that is why preserving these points is vital to get successful middle turbinate flap[20,38,40]. Elsheikh and El-anwar stated that the partial necrosis of the middle turbinate especially the inferior part occurred due to SPA ligation, while the superior part still vital, giving a hint that this part may receive additional blood supply from other sources[41]. In conclusion, the middle turbinate receives its main blood supply from the PLNA which approaches from behind, while the anterior sources of blood supply to the turbinates, when

present, can be sacrificed in cases when middle turbinate flap is needed to close a skull base defect[42].

The inferior turbinate and its blood supply, the bulk of this study, consist of a bony core, the inferior concha, which is a separate bone that articulates with the conchal crests of palatine and maxillary bones, posteriorly and anteriorly respectively[4]. The bone is covered by mucosal layer which contain venous sinuses and erectile tissue. The inferior turbinate may hypertrophied and even block the nose, affecting the air flow at the nasal valve, which it forms its posterior limit. The clinical anatomy of the inferior turbinate acquired a great deal of interest recently, due to the development of surgical procedures involving turbinate resections in cases of turbinate hypertrophy. The major intra- or postoperative complications belong to haemorrhage. Furthermore, the blood supply of the inferior turbinate plays a major role in planning of flap surgeries for skull base reconstructions. Hence, it is worthy to get thorough anatomical information about the inferior turbinate and its blood supply. In this study, the length of the inferior turbinate, blood supply, site of entrance of ITA, length and diameter of ITA, branching pattern of the artery, and the presence of bony canals within the turbinate for the arteries were investigated. It was found that the average length of inferior turbinate was 45.81 ± 3.257 mm, which is close enough to previous studies mentioned its length as average 48.7 mm in men, and 47.3 mm in women[43]. We did not regard the sex difference here.

The inferior turbinate artery, which is normally one of the terminal branches of PLNA, courses downward in the mucosa of the lateral nasal wall in one of two recognized patterns; the first when the artery make a curve forward for a while then continue downward to the turbinate. The second pattern, when the artery passes steeply downward to reach the turbinate. In both conditions, the artery approaches the turbinate from its superior surface and about of 7.87 ±1.529 mm in average from its posterior end. During its course downward, the artery was noticed to leave a

groove on the bone of lateral wall in two cases. The site of entrance of the ITA to the inferior turbinate was described by previous studies as to be 1.0 and 1.5 cm from the posterior end of the turbinate [20,38]. While Mustafa *et al.* mention the average distance as 7.2 mm and Burnham stated that the artery reaches the posterior tip of inferior turbinate bone[19, 34] . Our results were close to Mustafa *et al.* findings and we did not found the distance of entrance of the artery to inferior turbinate to exceed 10 mm just in two cases out of forty. Thus, in the majority of cases the site of the artery entrance was within the anterior half of the first centimeter of the posterior end of the inferior turbinate. This should be kept in mind during surgical interventions involving the inferior turbinate.

On entering the inferior turbinate, the ITA artery divides into two or three branches that pass forward in the turbinate. During their course within the turbinate, we found them to lie in bony canals, and within these canals the arteries were wrapped by a fascial coat that is attached to them and to the canal firmly. That's explain the occurrence of prolonged bleeding after the surgical trimming of the inferior concha, due to the inability of the artery to contract because of that fascial coat which hold the artery opened. Padgham and Vaughan-Jones, and Hadar *et al.* mentioned the presence of such bony canal in their study on cadaveric heads[20,44]. Burnham describes details about these canals[19], while Mustafa *et al.* did not found any bony canals in their study, although they stated that there were close relation of the artery to the bone[34].

In the present study, we found that the inferior turbinate artery from the PLNA was the main blood supply of the inferior turbinate; in addition, it gives an antral branch that travel toward the fontanelle. The ITA was found to be supplemented by other branch from descending palatine artery which enters the nasal cavity through an accessory foramen in one case. The accessory artery found to converge with the ITA of the PLNA and continue downward as single artery.

Mustafa *et al.* describe a similar condition of supplementation of ITA with branches of descending palatine artery[34]. Furthermore, Burnham mentioned that a branch from descending palatine found occasionally and participate in the supply of the inferior turbinate from behind[19]. While Hadar *et al.* decline the presence of such additional arterial blood supply[44]. In one case through this study, we found the inferior turbinate was supplied by a branch which came from descending palatine artery, not from PLNA, this artery was the main supply to the turbinate and takes the course similar to the IT when it came from PLNA. Lee *et al.* mentioned that the inferior turbinate was supplied mainly by a branch came directly from the descending palatine artery in one case out of fifty he studied[28]. This type of variations, when present, may explain failure of the control of posterior bleeding – epistaxis- although the traditional managements were applied.

During their course in the inferior turbinate and while approaching its anterior end, the branches of the ITA become smaller in diameter. But it is worthy to note that these branches may show a marked increment in the diameter, a sign of additional blood flow from anterior [20]. In the present study, we encountered such condition in front of the inferior turbinate and in some cases just above its anterior end. There was a clear anastomosis between the terminal branches of ITA and that's of anterior ethmoidal artery and/ or branches of facial arteries which encroaches through the nares. In these conditions, it is clear that these artery participate in the supply of the inferior turbinate, although to much less extent, as it is evident by the great differences in the diameter of the arteries which pointed to the dominant arterial blood supply. Nevertheless, these anatomical facts were mentioned by previous author's works[19, 20]. While Hadar *et al.* denied the presence of anastomosis between ITA branches and anteriorly coming arteries[44]. Gil and Margalit take the advantage of the presence of the anastomosis in front of the inferior turbinate for the planning of anteriorly based flap of inferior turbinate to reconstruct skull base defects[33]. Furthermore, the extensive works of Hadad *et al*. on anterior pedicle nasal

flaps gave an evident of the dual supply of the inferior turbinate from both ITA and branches from facial artery and anterior ethmoidal artery[45].

Inferior turbinate hypertrophy which is one of the common otolaryngological problems needs surgical reduction of the turbinate to improve the airway passage. During turbinectomy, the surgeons notice that there was no massive bleeding when removing the anterior or inferior part of the inferior turbinate, the operation which is used to open the anterior nasal valve, mean while, a more bleeding was expected when removing the posterior part. This gives a clue to the site of the main artery that supply the inferior turbinate, but it not canceled the presence of small contribution from anteriorly located arteries that come from other sources.

6. CONCLUSIONS and RECOMMENDATIONS

The main blood supply of the lateral wall of the nasal cavity was the sphenopalatine artery, one of the terminal branches of the maxillary artery, which is in turn one of the terminal branches of the external carotid artery. Although additional blood supply was found from the anterior and posterior ethmoidal arteries (branches from ophthalmic artery of the internal carotid), the descending palatine artery, and the facial artery through its lateral nasal branch. The latter participate in anastomosis in the lower anterior part of the lateral wall, infront of the inferior turbinate.

The superior turbinate is supplied largely by a branch which is either comes directly from the SPA or from the nasoseptal branch. İn contrary to what is mentioned in some otolaryngological books as the superior turbiante is the territory of only the ethmoidal arteries with no mention to the role of SPA or NSA in the blood supply of it.

The ethmoidal arteries participate in the blood supply of the superior turbinate, lateral wall anterior to the turbinates, and anastomose with the terminals of the inferior turbinate artery infront of / or just above the anterior end of the inferior turbiante. The surgeons take advantage of this fact in planning for anteriorly based flap in cases when the posterior one was unapplicable.

The middle turbinate receive its main blood supply from middle turbinate artery, branch of posterior lateral nasal artery of sphenopalatine, that artery approach the turbinate from its posterior end. Nevertheless, the middle turbinate artery may arise at a lower level from the posterior lateral nasal artery and take upword course in the middle meatus to reach the turbinate from below its posterior one-third, this position may be in danger during surgeries involving the maxillary air sinus or utilizing this area as a rout for other procedures.

The inferior turbinate artery, which is one of the terminal branches of posterior lateral nasal artery, is the main blood supply of the inferior turbiante. İt approaches the inferior turbinate from above at a distance less than 1 cm in

average from its posterior end, not entered from the posterior tip. Within the turbinate the artery divides and run in bony canals. This fact should kept in mind during procedures include trimming of the inferior concha and distruction of such canal, as the artery covered by fascial coat that attaches its wall to the wall of the canal, this condition may impede the contraction of the artery after injury and lead to prolonged bleeding.

Variations in the origin of the inferior turbiante artery was found as the artery came from the descending palatine not from the usual origin which is the PLNA, a condition may leads to unexpected bleeding even with procedures include the cauterization of SPA.

The diversity of the shape and course of the ITA should be noted in planning for operations that involved cauterization of the artery, or in planning for posterior pedicled nasal flap.

It was noted that there is anastomosis between the terminal branches of inferior turbinate artery and the anterior ethmoidal and/or the facial branch. The anastomosis may provide a source of blood supply to the anterior end of the inferior turbinate. The anastomosis found anterior to /or above the anterior end of the turbinate, not within its substance.

From all the above, it is clear that why in the surgical procedures that envolved embolization or cauterization of SPA, there are complications appeared during follow up the patients includes sinusitis, and crusting of the turbinates.

A future cadaveric studies using large numbers of fresh cadavers, even not frozen, may give a better understanding of the anatomy and the distribution of the arteries, especially, when such studies aided with colorization of the arteries. Furthermore, radiological aided cadaveric study, whether CT scan angiography or digital subtraction angiography, to visualize small arteries, will be of great value to evaluate the blood supply of the nasal cavity.

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APPENDIX 1. ETHICAL COMMITTEE APPROVAL

T.C.
HACETTEPE ÜNİVERSİTESİ
Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu

Sayı : 16969557-983

ARAŞTIRMA PROJESİ DEĞERLENDİRME RAPORU

Toplantı Tarihi : 02.09.2015 ÇARŞAMBA
Toplantı No : 2015/18
Proje No : GO 15/390 (Değerlendirme Tarihi: 27.05.2015)
Karar No : GO 15/390 – 04

Üniversitemiz Tıp Fakültesi Anatomi Anabilim Dalı öğretim üyelerinden Doç. Dr. İlkan TATAR'ın sorumlu araştırmacı olduğu, Doç. Dr. Burçe Özgen MOCAN ile birlikte çalışacakları Arş. Gör. Asaad AL SHOUK'un tezi olan GO 15/390 kayıt numaralı ve ***"Concha Nasalis Inferior ve Burun Lateral Duvarının Kanlanması"*** başlıklı proje önerisi araştırmanın gerekçe, amaç, yaklaşım ve yöntemleri dikkate alınarak incelenmiş olup, etik açıdan uygun bulunmuştur.

1.Prof. Dr. Nurten Akarsu (Başkan)
2. Prof. Dr. Nüket Örnek Buken (Üye)
3. Prof. Dr. M. Yıldırım Sara (Üye)
İZİNLİ
4. Prof. Dr. Sevda F. Müftüoğlu (Üye)
5. Prof. Dr. Cenk Sökmensüer (Üye)
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APPENDIX 2.

Table shows measurements of ITA and ITA measurements related to other anatomical landmarks. All measurements are in mm.

No. and side	Diam-eter of ITA	Length of ITA	Distance from post. end of IT	Distance from choana	Distance from auditory tube opening	Distance from entrance of ITA to IT and SPF	Length of IT	Distance from ant. nasal spine
1 RT	1.35	8.5	10.2	13.9	13.9	11.77	32.89	41.41
1 LT	1.45	8.37	8.4	8.65	12.94	12.7	37.5	41.41
2 RT	1.5	5.2	6.77	11.16	14.34	10.66	42.05	38.57
2 LT	1.48	5.12	8.81	11.8	13.5	11.88	46.61	48.33
3 RT	1.3	8.02	7.38	8.8	13.5	11.7	44.31	48.19
3 LT	1.25	10.02	6.41	7.32	11.8	10.44	47.62	53.63
4 RT	1.41	10.25	9.24	12.74	17.07	11.99	49.52	47.24
4 LT	1.24	9.35	7.27	11.15	13.9	13.7	47.47	52.24
5 RT	2.06	12.46	10.3	14.7	17.52	15.07	46.03	52.42
5 LT	1.7	9.05	7.25	8.15	17.04	12.6	45.7	49.06
6 RT	1.27	7.97	8.9	10.89	17.6	13.8	47.04	49.03
6 LT	1.25	11.1	9.04	13.3	17.56	12.79	45.01	46.5

7 RT	1.41	9.72	9.46	13.71	16.1	10.4	46.3	46.5
7 LT	1.36	7.88	9.54	12.67	14.08	12.27	47.4	47.8
8 RT	1.53	11.22	7.02	12.87	14.7	13.8	44.68	49.41
8 LT	1.5	9.69	7.67	11.11	14.58	12.61	45.4	48.63
9 RT	1.5	9.47	7.97	11.31	14.78	12.81	45.91	48.86
9 LT	1.6	8.29	9.13	10.8	13.6	14.6	45.71	49.1
10 RT	1.5	7.44	9.13	11.02	14.21	14.5	50.15	53.8
10 LT	1.6	5.64	7.05	10.21	13.9	13.9	50.8	55.05
11 RT	1.37	6.55	8.91	13.74	17.08	13.33	51.25	54.5
11 LT	1.39	9.98	7.89	13.21	14.6	12.81	50.1	50.6
12 RT	1.46	9.3	12.02	13.01	15.9	11.5	46.9	47.2
12 LT	1.82	9.67	7.64	11.51	14.03	12.92	47.59	41.71
13 RT	1.6	8.31	8.56	13.12	16.9	13.13	47.2	49.57
13LT	1.5	7.38	8.41	12.5	12.6	12.72	47.82	52.57
14 RT	1.34	7.56	6.89	9.9	13.2	10.9	45.8	49.35

14 LT	1.35	11.25	8.62	12.3	15.2	10.83	44.26	50.28
15 RT	1.61	10.5	6.5	10.75	14.11	10.36	45.9	52.49
15 LT	1.5	7.81	6.55	10.05	13.44	12.04	43.51	51.48
16 RT	1.58	8.56	5.44	8.74	14.95	10.96	43.15	48.2
16 LT	1.5	8.92	6.56	11.2	14.6	12.7	46.85	55.1
17 RT	1.34	9.56	4.79	7.68	12.64	15.5	45.8	53.29
17 LT	1.45	9.62	4.46	6.23	13.09	16.63	44.1	48.55
18 RT	1.6	11.28	9.44	12.21	14.94	13.9	44.54	48.21
18 LT.	1.32	11.02	6.57	8.02	12.85	12.17	43.13	43.49
19 RT	1.15	10.58	8.12	12.21	16.23	14.48	47.85	44.58
19 LT	1.25	10.15	7.09	12.56	15.19	13.07	46.65	47.01
20 RT	1.45	9.95	7.32	11.26	14.6	12.81	45.82	52.2
20 LT	1.26	9.59	6.45	12.03	14.55	11.89	46.23	51.21

Curriculum Vitae

1. Identification:

1. Full name: Asaad Abd Al-Hussain Mohammad AL-SHOUK
2. Gender: Male.
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2. Degrees and Qualifications:

1. M.B.Ch.B. Bachelor of Medicine and Surgery, College of Medicine, University of Kufa- Iraq. 1998.
2. Master degree in Human Anatomy from College of Medicine, Al-Nahrain University. Baghdad - Iraq. 20th March 2007.
3. Registration and practice certificate as a member of Iraqi Medical Association, 16th September 1998.

4. Scientific and Academic position:

1. Assistant lecturer in College of Medicine- Qadisiya University-Iraq, department of Anatomy. Since 2007.

5. Associations and societies:

1. A pass certificate in a living foreign language proficiency test at Test Center in University of Babylon, College of Education, 16th April 2000.
2. A pass certificate of the course in computer held in Computer Center of Babylon University, 17th January 2000.
3. A pass certificate in workshop in Immunohistochemical Technique, College of Medicine- Qadisiya University, 2007
4. A pass certificate in workshop in Polymerase Chain Reaction, College of Medicine- Qadisiya University, 2008
5. A pass certificate in Technical Training in Using Technology in Education, University Center for Excellence, Qadisiya University. 2009.

6. Clinical Activities:

1. 1998-2000: Internship residency at Marjan Teaching Hospital of internal medicine and cardiology. Babylon- Iraq.
   Internship residency at Babylon Teaching Hospital for Pediatrics and Gynecology.

   Internship residency at Al-Hilla Teaching Hospital for Surgery.
2. 2000-2002: Internship residency at Field Medical Unit, Baghdad Forces, Republican Guard.
3. 2002-2003: A master of unit in Primary Health Care Center in Babylon.
4. Permanent resident in Medicine-Rheumatology, Marjan Teaching Hospital, Babylon- Iraq.
5. Manager of Popular Clinic in Diwaniya City- Iraq.

7. Research activities , publications, and conferences:

1. Changes in the superior zygapophyseal joints in the lower thoracic and upper lumbar vertebrae in Babylon population. Research paper.
2. Effect of gentamicin on the histology of renal tubules in different doses, experimental study. Research paper.
3. Cadaveric approach to the muscle and fascia of the male perineum. Uğur Baran Kasırga, Asaad El-Shouk, Hasan ILgaz, Neşe Çetin, Alper Vatansever, Seda Uygun, Aziz Jon Achilov, Mustafa Sargon. Presentation in 1st International Uroanatomy congress. TURKEY Izmir, 2013
4. perineal approach to the prostate: A cadaveric study. Alper Vatansever, Neşe Çetin, Hasan Ilgaz, Asaad El-Shouk, Seda Uygun,Uğur Baran Kasırga, Aziz Jon Achilov, Mustafa Sargon. Presentation in 1st International Uroanatomy congress. TURKEY .Izmir, 2013
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