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RESEARCH ARTICLE

NERVE BLOCKING AND THE BRACHIAL PLEXUS SHEATH IN THE INTERVERTEBRAL SPACE

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A thesis submitted for the degree of Postgraduate Diploma in Science At the University of Otago, Dunedin, New Zealand.

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Key words:-
Brachial plexus, nerve block , intervertebral space.

Abstract

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Introduction:- There has been an increased demand for regional anaesthetic block of the brachial plexus during upper limb and shoulder surgeries. The brachial plexus (BP) is formed by the anterior rami of spinal nerves C5 - T1. These nerves are enclosed by a fascia-like structure called the fascial sheath, which performs an important role in localization of intramuscular anaesthetic agents. It is thought that the brachial fascial sheath is continuous with the prevertebral fascia which is the deepest layer of the deep cervical fascia. However a systematic search of the literature has shown this description still remains unclear. Therefore, it is hypothesize that the brachial fascial sheath has multiple fascial origins, such as the meninges and prevertebral fascia. The aim of this study is to identify the anatomical relationship between the roots of the brachial plexus and the surrounding structures in the intervertebral space.
Materials and Methods:- Specimens from 7 cadavers (ages 75-86 years, 3 males) were used for this project. Guided by ultrasound, the structural landmarks around the BP of one cadaver were determined and an 18 guage needle was then located to the tip of the C5 transverse process and 20ml of blue-coloured latex was injected into this area. A layer-by-layer dissection approach was performed to expose the location of the injected latex. Six sets of E12 slices were obtained from six cadavers (one coronal, two sagittal, three transverse). These slices were examined macroscopically and sub- microscopically. Digital photographs of the gross anatomical dissection, E12 slides and ultrasound scans were taken by digital camera.
Results:- The latex was entirely located deep to the prevertebral fascia. The root of the nerve was covered by not only by the prevertebral fascia but also had its own covering, or the root covering proper. This covering proper extended towards the intervertebral space but became undetectable at the tip of the transverse process. The dura mater was fused with the periosteum of the associated vertebra. There was no fascia-like structure around the nerve in the intervertebral space. In the intervertebral spaces, the nerve contacted with the vertebral artery and was surrounded by rich vascular networks.
Conclusion:- The brachial plexus sheath has multiple origins, making the precise placement of anaesthetics essential to achieve effective

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local blocking of the plexus. The extensive vascular network surrounding the nerves in the
intervertebral space leads us to suggest injection of local anaesthetics into this space would not be recommended.

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List of Abbreviations:-

BP = Brachial plexus
BPS = Brachial plexus sheath C = Cricoid
CA = Content of the sheath
CARA = Clinical Anatomy Research Area C#-T# = Cervical vertebra, Thoracic vertebra CL = Clavicle
cm = Centimetres D = Dura mater
E12 = Epoxy sheet plastination F = Root covering proper GA = Spinal nerve
IS = Intervertebral space JN
= Jugular notch
LX = Latex
M = Mandible mm
= Millimetres
N = Nerve leaving the foramen NR
= Nerve root
n = Nerve Branch P
= Periosteum
PF = Prevertebral fascia
S = Sternocleidomastoid + Root covering proper SA = Scalenus anterior
SCM = Sternocleidomastoid SG
= Submandibular gland
SL = Area underneath the skin T
= Thyroid
T = Trapezius
USA = United States of America VA
= Vertebral Artery

Introduction:-

Regional anaesthetic block of the cervical plexus has been the preferred option for some surgeries of the upper extremities, especially shoulder surgeries (Neal et al., 2002). Brachial plexus block is one of the techniques of providing anesthesia to the upper limb during surgeries (Tran et al., 2007), and many approaches of the brachial plexus block have described in the literature (Appendix A). The brachial plexus is formed by the anterior rami of spinal nerves C5 - T1, with anatomical variants receiving contributions from C4 and T2 (Longnecker et al., 1998). The nerves are surrounded by fascial sheath called the brachial plexus sheath (BPS) which has been suggested as having an important role in the localisation of the intramuscularly injected anaesthetic agent. A substantial review of the literature has highlighted the description of the BPS as a subject of debate (Appendix B). Popular description states that the brachial plexus sheath is continuous with the prevertebral sheath, which is a part of the deep cervical fascia (Grodinsky and Holyoke, 1938).

Hayes, 2008). However, recent research has challenged this concept. Cornish and his colleagues (Cornish et al., 2007; Cornish and Leaper, 2006) found no brachial sheath and the plexus was surrounded by rigid structures, such as muscles and vascular vessels. Nash et al. (2005) used a combination of dissection, E12 sheet plastination and confocal microscopy to examine the fascial structures in the anterior cervical triangle in 10 adult human cadavers (aged 67-89 years). They found that the superficial layer or investing layer of the deep cervical fascia does not exist in the human neck.

From this, it is still unclear whether and how the BPS continues with the deep cervical fascia.

According to (Weller, 2005), underneath the prevertebral fascia, the spinal meninges (dura, pia and arachnoid) form a sleeve like structure encasing the nerve travelling through the intervertebral foramen. The nerve then runs between the transverse process of the cervical vertebrae in a space called the intervertebral space.

These findings raise a fundamental question: what is covering the segment of the cervical nerves in the intervertebral space underneath the prevertebral fascia?

It is hypothesized that the brachial sheath has multiple origins, and may be continuous with the meninges and the prevertebral fascia.
The aim of this study is to identify the anatomical relationships between the roots of the brachial plexus sheath and the surrounding structures in the intervertebral space.

This will be accomplished by using a combination of techniques, which include ultrasonography combined with gross anatomical dissection, macroscopic description and quantitative analysis of E12 plastinated specimens.

It is expected that this study will be of use to clinicians for improving their techniques regarding the brachial plexus nerve blocking.

Methods and Materials:-

Cadaveric Material: A total of seven adult human cadavers (ages 75-86, 3 males and 4 females) embalmed with Anatomical Mix (Dodge Anatomical Mix, Dodge Chemical Company Inc., 4% formalin, methanol based, Cambridge, Massachusetts, USA). One cadaver (0381/7) used for ultrasound and gross dissection, and six cadavers for image analysis (previously prepared E12 plastinated specimens). All bodies were donated to the Department of Human Anatomy and Structural Biology (University of Otago, Dunedin) under the Human Tissue Acts of 1964 and 2008.

Other Materials: Ultrasound Machine (The Shimadzu Corporation (Kyoto), Main Unit, SDU-350XL; 7.5MHz Handpiece, L070-075U) and digital cameras. The digital cameras are: 14.7 Mega Pixel camera (Canon powershot G10, Canon Corporation, Japan) and Nikon Coolpix 990 digital camera (3.34 mega pixel, Japan). A microscope with a digital camera and Macintosh computer systems were used for further analysis and storage of the results.

Gross anatomical methods:-

Cadaver 0381/7 (83 years, male) was prepared for dissection. The landmark structures were externally located by palpation; these were the mandible bone, thyroid cartilage and gland, cricoid cartilage, scalenus anterior muscle, jugular notch, the anterior and posterior border of the sternocleidomastoid muscle, and the base of the posterior triangle of the neck the superior surface of the clavicle (Figure 1A). The cricoid cartilage was marked on the skin using a permanent marker pen below the thyroid cartilage and above the thyroid gland.

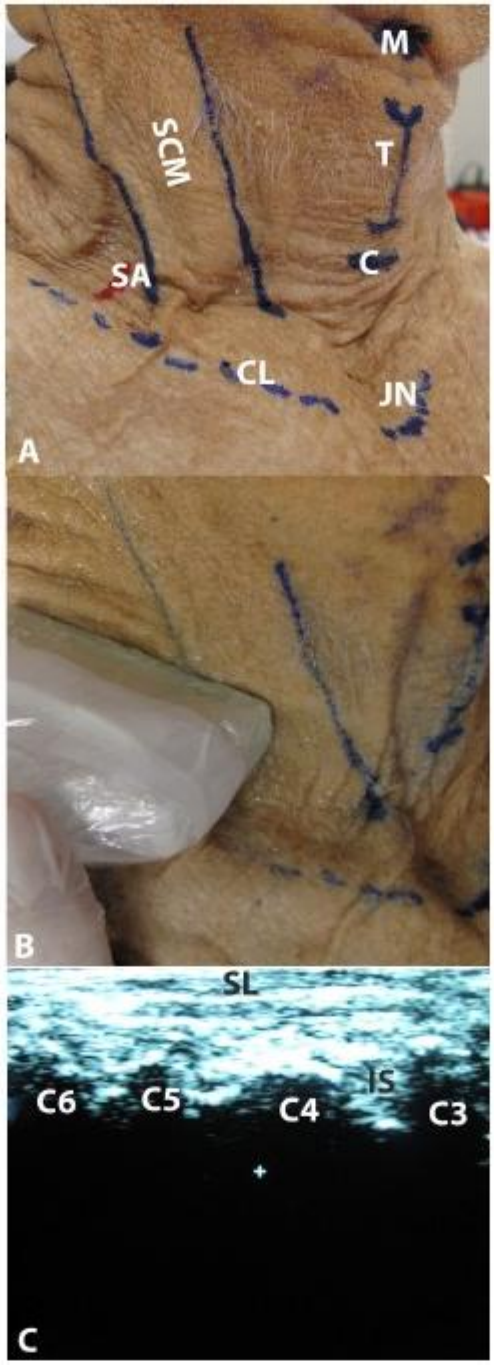

Figure 1:- Localization of the land marks for latex injection. (A) The surface marks on the neck. CL=Clavicle, C=Cricoid, SCM=Sternocleidomastoid, T=Thyroid, SA=Scalenus anterior, M=Mandible, JN= Jugular notch. (B) Ultrasound scans for guiding latex injection. (C) An example of ultrasound images showing the transverse process of the cervical vertebrae (black areas, labeled C3 – C6) and intervertebral spaces (white areas, labeled 'IS"). SL indicates the area underneath the skin.

The bony surface of the clavicle was observed and a horizontal line was drawn along the clavicle. The sternocleidomastoid was determined by a vertical line drawn from the clavicular head to the hyoid bone level. The jugular notch was marked at the sternal end of the clavicle. The scalenus anterior was marked by red marker at the inferior end of the posterior border of the sternocleidomastoid.

Ultrasound was used to locate landmark structures internally, the intervertebral space between the cervical transverse processes of C3-C6, and to guide the needle while injecting the cadaveric neck. After locating and determining the landmark structure, to increase the intensity of ultrasound waves entering the cadaveric skin an ultrasound gel (Parker Laboratories, New Jersey) was used. A vertical scan was performed on the specimen to locate the scalenus anterior muscle (Figure. 2B). In addition, a horizontal scan was also preformed to visualize the transverse processes of the cervical vertebra and the intervertebral space (Figure. 2C). Using ultrasound to guide, an 18 gauge needle with a 20ml syringe was inserted at a 60O degree angle, at the location of the tip of the C5 transverse process, and 20 ml of the blue-colored latex was injected. Blue coloring was used as a contrast for later dissection. The specimen was kept overnight at room temperature to allow the latex to cure.

A layer-by-layer dissection was conducted to reveal the location of the injected latex. The dissection was performed in the Clinical Anatomy Research Area (CARA) in the Department of Anatomy and Structural Biology at the University of Otago. All sharp dissections were done with a #20 scalpel blade on a #4 handle. The right side of the cadaver was fully dissected prior to commencing on the left side. The neck was kept in the anatomical position throughout the dissection.

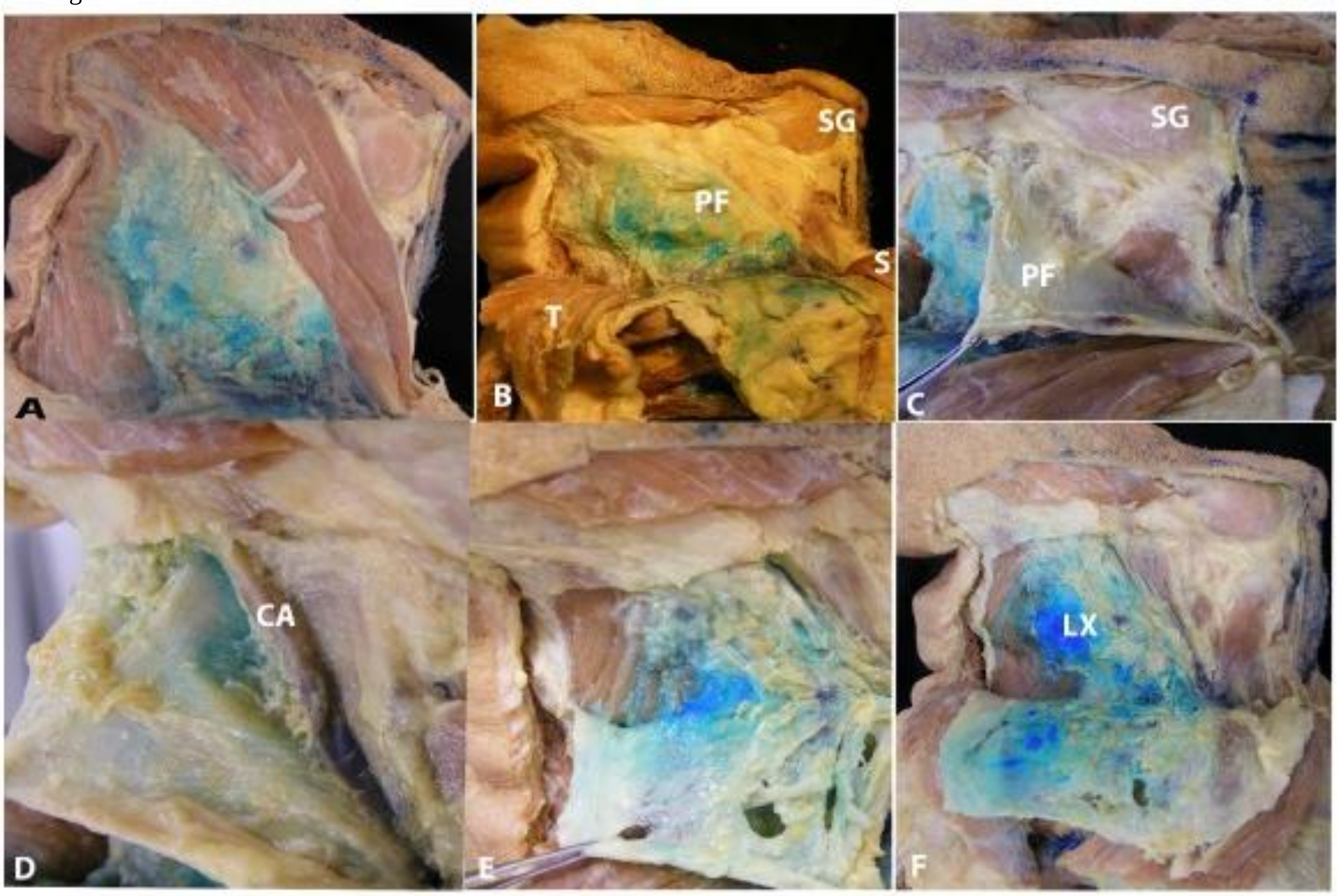

Figure 2:- A layer-by-layer dissection to reveal the location of the injected latex. A & B: before and after the sternocleidomastoid (S) and trapezius (T) were cut and reflected inferiorly, respectively. PF = prevertebral fascia. C: Opening the fascia (PF) that covers the infrahyoid muscles and submandibular gland (SG). D: Opening the carotid sheath. Ca represents the contents of the sheath. E & F: showing the injected latex (LX) underneath the prevertebral fascia (PF).

In order to remove the skin (epidermis and dermis), the initial incision was a vertical one over the anterior border of the sternocleidomastoid muscle. This was followed by a horizontal incision along the border of the clavicle. The removal of the skin progressed until the borders of the trapezius were observed. The complete removal of the skin exposed a layer of superficial adipose tissue, which was removed by forceps and sharp dissection blades. Once the adipose layer was removed, the superficial fascia was exposed and observed to be enveloping the platysma muscles.

The platysma muscle was cut and reflected inferiorly to expose the superficial fascia of the deep cervical fascia. The removal of the superficial fascia exposed the sternocleidomastoid and trapezius muscles (Figure. 2A), which were then cut and reflected inferiorly to reveal a fibrous connective tissue called the prevertebral fascia of the neck (Figure. 2B). The prevertebral fascia was further dissected to reveal the latex and the deep cervical muscles (Figure. 2C).

Epoxy Sheet Plastinates (E12):-
Six sets (one coronal, two sagittal, three transverse) of previously prepared E12 sheet slices were obtained from six cadavers. The thickness of the slice was 2.5-3 mm, with a tissue loss of 5mm between each slice. Two transverse sets are housed in the Anatomy Museum in the University of Otago Medical School for teaching, and one transverse set had been prepared in the Clinical Anatomy Research Group Lab, Department of Anatomy and Structural Biology (University of Otago). The two sagittal sets were obtained from the Anatomy Museum and the coronal set was obtained from the Clinical Anatomy Research Group Lab. The process of preparing the E12 slices is described in (Nash et al., 2005a).

All data were collected from these sets. These slices were examined macroscopically and sub-macroscopically.

Imaging and evidences collection:-
At every level of the dissection and ultrasound results were taken by a digital camera. The camera was 14.7 Mega Pixel (Canon powershot G10, Canon Corporation, Japan). Photographs of the all slices were taken at the sub-macroscopic level using a Nikon Coolpix 990 digital camera (3.34 mega pixel, Japan). To enhance the sub-macro photographic application the camera was fixed on to a Mine Repro (Italy) photographic camera stand.

The Mini Repro is fitted with a three-faceted geared column, 70 cm high mounted on a 42X40 cm base-board (model number Cod. 1190). Images of the slides were taken while the digital camera was positioned 60 cm above the base board (as measured by the built-in measure on the Mini Repro). The camera was set on automatic focusing with the auto correction of high magnification, and the slices were on top of a backlight unit sitting upon the baseboard (Medalight®, slim light panel, LP 400, viewing area 20*30 cm, Thailand). The transverse sections that contain C8-T1 vertebra were taken while the camera was positioned 30 cm above the base board.

The photo data was transferred from the camera, and stored on the Macintosh computer system (Mac OSX, version 10.5.8, Singapore) in the Clinical Anatomy Imaging Room. The images were entered into Photoshop®, and using the photomerge feature, the images were mosaicked together to create high resolution image of each individual slice.

At the sub-macroscopic level a number of the transverse and sagittal sections were further examined under Leica MZ8 stereomicroscope with a transmitting light stand HL. The microscopic images were taken by Leica MP60 photo automate (Leica Microscopy Systems Ltd, Business Unit SM, CH-9435 Heerbrugg, Switzerland) at magnification ranging from 0.65 to 5 times. For each picture taken, the shot number, magnification power, light exposure time, slice ID number, field feature and general impression of the image were recorded in a table on a separate sheet. Each sheet is attached to its correspondent developed film. A total of three Kodak Ultramax colour negative films (ASA 400, 36 mm, Mexico) were used for collecting data. The processed films was scanned by scanner (Epson Perfection V700 Photo, J221A, Indonesia) set at 6400 dpi in the Department Anatomy and Structural Biology and stored in Macintosh computer in the Imaging Room Analysis for further examination.

Results:-

Gross anatomical examination:-
The latex injection proved to be a valuable technique for visualising the borders and area that were injected. Upon dissection, the spread of the latex was limited to underneath the prevertebral fascia (PF) following injection into the interscalenus space (Figure 2). The prevertebral fascia (PF) was bordered by the sternocleidomastoid (SCM) and the trapezius muscles in the posterior triangle of the neck (Figure 2A). Moreover, the PF appears as a fibrous connective tissue that extends downwards and laterally behind the carotid vessel and continues under the clavicle. The anterior

triangle was bordered by the submandibular gland inferiorly to the mandible and anteriorly to the sternocleidomastoid. The latex did not spread into the anterior triangle (Figure 2A, B, C). The sternocleidomastoid, trapezius was cut and reflected inferiorly. On the deep surface of the SCM, the SCM sheath was not infiltrated by the latex and the infrahyoid muscle sheath (Figure 2B, 2C). A portion of the prevertebral facia was noted as enclosing the carotid artery, the vagus nerve and the internal jugular vein (the carotid sheath). The latex was not found in this sheath (Figure 2D).

After the PF was dissected, a large blue area was noted on a fascia-like structure covering the surface of the deep cervical muscles, such as the scalenus anterior. This fascia like structure appeared as a dense fibrous connective tissue which was mixed with a fatty, yellow layer (Figure 3B). This was further dissected to reveal the surface of the deep cervical structures. The latex spread over and into the deep muscles near the injection, such as the scalenus anterior site but not into other muscles (Figure. 2E, F and 3B and C).

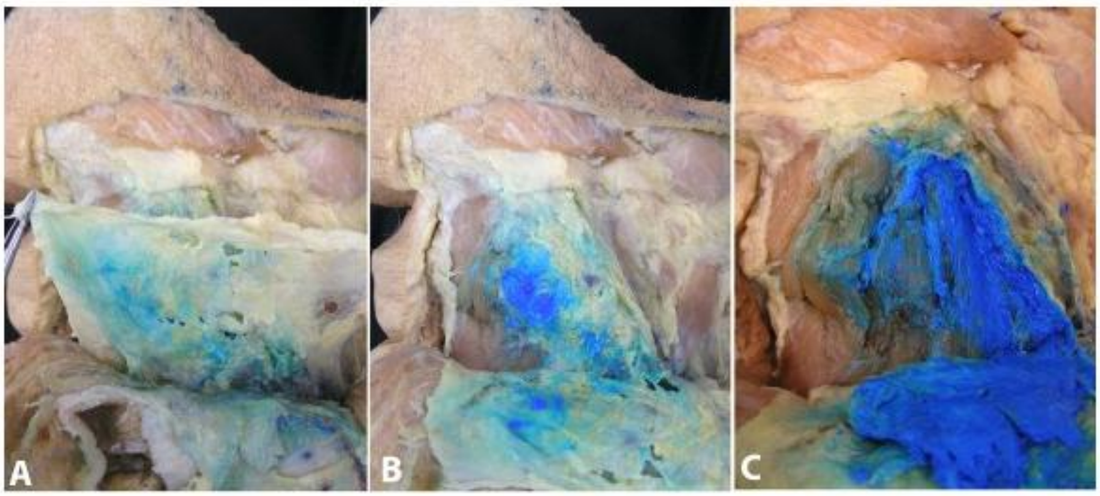

Figure 3:- Spread of the injected latex. A: The forceps holding the prevertebral fascia. B & C: The injected latex spreads into some but not all of the deep cervical muscles.

To examine the origin of the sheath around the nerve root further dissection was made (Figures 4 A-F). Two fascia like structures were noted. The prevertebral fascia covers the muscular structure and nerve fibers (Figure 4A). Moreover, the root of the nerve root of the brachial plexus not only was covered by the prevertebral fascia but also had its own covering (Figure 4B). This is called “the root covering proper”. The nerve fiber was embedded between the scalenus anterior and the scalenus medius (Figure 4C). Throughout the dissection, the root covering proper becomes more homogenous with the muscular fascial layer (Figure 4D). The intervertebral space is located between the lower edge of the transverse process above and the upper edge of the transverse process below (picture not shown). When the fascia like structure around the nerve root is traced towards the intervertebral space (black area Figure 4E) it disappears at the tip of the transverse process and underneath the intervertebral space (Figure 4F).

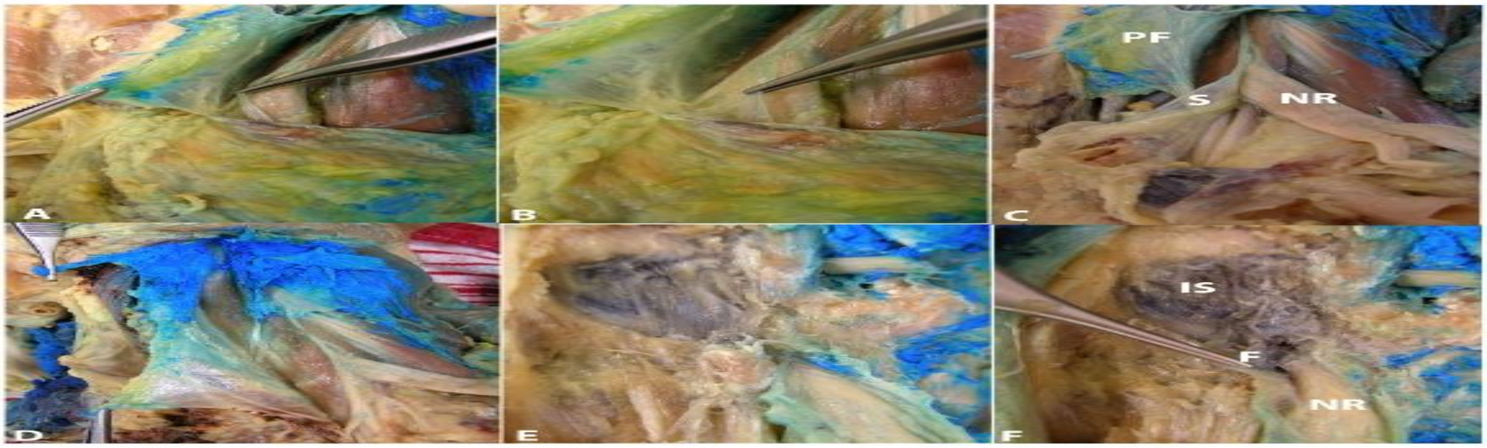

Figure 4:- Coverings of a root of the brachial plexus. A & B: The blunt and sharp forceps hold the prevertebral fascia and the root covering proper, respectively. C: The root covering proper (S) follows the root (NR) and extends into the deep cervical muscles. D-F: Tracing the root covering proper (F) to the intervertebral space (IS).

E12 plastination examination:-

The subsequent findings were based on the observation of the serial E12 epoxy slices with thickness of 2.5-3 mm. The results of this part of the study were obtained from two methods: macroscopic and microscopic observations.

At the microscopic level, in the intervertebral foramen, the ventral and dorsal nerve root join away from the spinal ganglion to form the spinal nerve. The dura mater is mainly fussed with the periosteum of the vertebra rather than travelling along the root of the cervical nerve. The spinal dura seems to run along the nerve, but before it reaches the vascular structure it looks to be attached to the periosteum (Figure 5A).

The Pia mater and the arachnoid mater fuse together at the intervertebral foramen which appears as a “V” shape (Figure 5A).

While the nerve travels through the intervertebral space, there is no fascia-like structure surrounding the nerve (Figure 5B). The nerve appears “nude” at this stage. Moreover, the nerve branch that travels from the main nerve root to reach the vascular structure is not enveloped by a fascia like structure (Figure 5B).

At the macroscopic level, the vertebral artery runs in the intervertebral space along with the nerve root (Figure 6 and 7). However, there is no fascia-like structure between the root of the nerve and the vertebral artery (Figure 6B-C). Furthermore, while examining the transverse sections (Figure 7A) microscopically the roots of the BP were surrounded by rich vascular networks at the intervertebral space level (Figure 7B). In summary, there are multiple origins for the covering of the BP. The nerve segment in the intervertebral space and the nerve root are “nude”, but surrounded with extensive vascular structure.

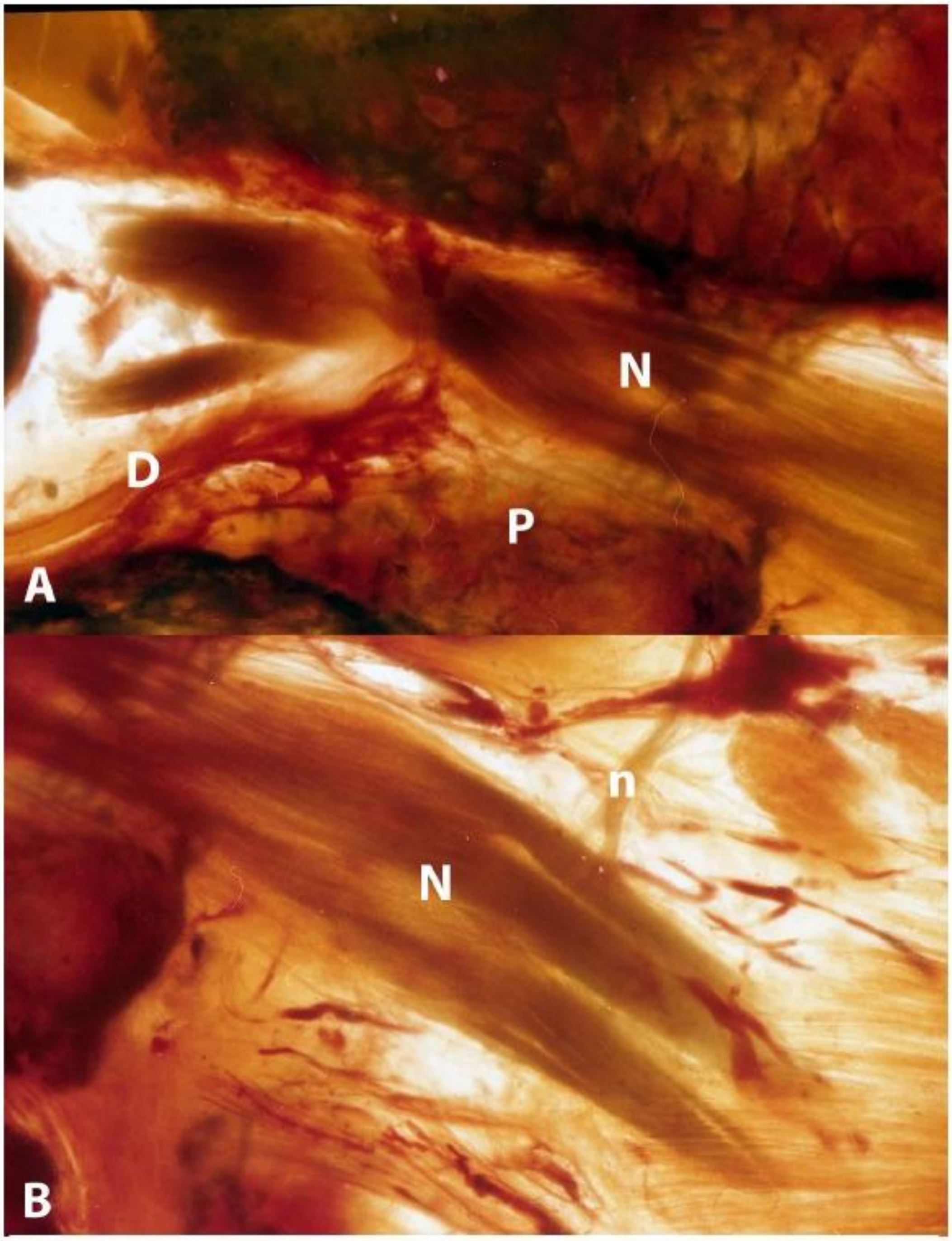

Figure 5:- The spinal nerve passes through the intervertebral foramen. A: The nerve (N) entering the foramen. The dura (D) mainly continues with the periosteum (P) of the vertebra. B: The nerve (N) leaving the foramen. No fascia-like structure can be clearly identified. (n) is a tiny branch to innervate the periosteum of the vertebra.

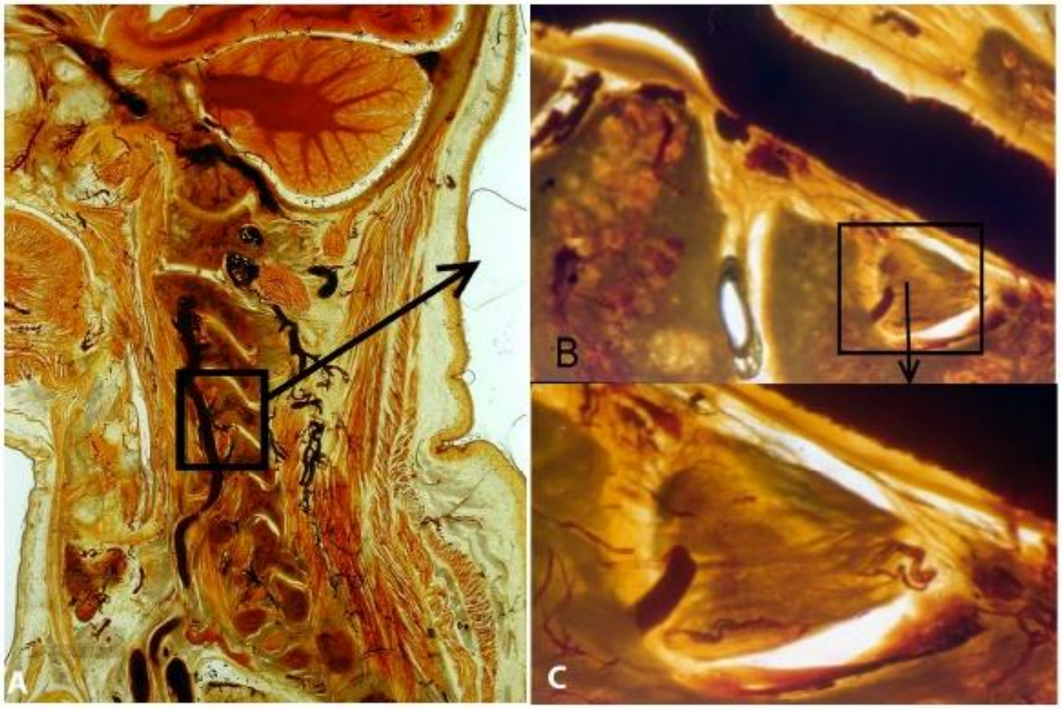

Figure 6:- A sagittal section showing relationship between the spinal nerve (G) and the vertebral artery (VA) with different magnifications (A-C).
Magnification levels: A= 0.65, B= 1.5, C= 2.0

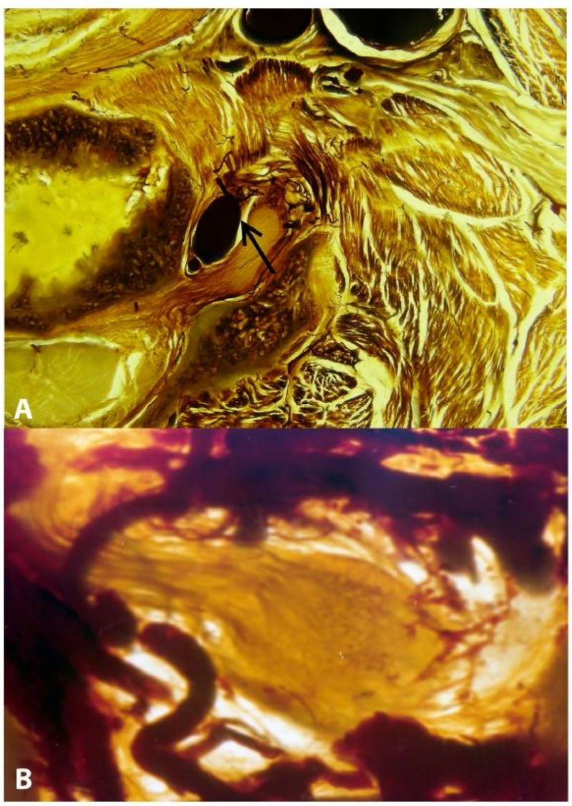

Figure 7:- Transverse sections show the relationship between the spinal nerves and the vascular structures. A: No fascia-like structure is found between the vertebral artery and the nerve (arrow). B: A rich vascular network surrounds the nerve.

Discussion:-

This study provides clear evidence to indicate that the sheath around the cervical nerve plexus has multiple origins and does not originate from the spinal dura as described in Weller (2005). Weller (2005) suggested that the spinal meninges, mainly the dura mater contribute to cover the nerve. However, this cannot be correct because the present study found that the dura fuses with the periosteum of the cervical vertebra. Furthermore, when the nerve travels beyond the intervertebral foramen, i.e., the intervertebral space, the vertebral artery always travels alongside the nerve, and the fascia like structure was not present around the nerve. Therefore, the tunica adverticia of vessels may contribute to the covering of the nerve.

This study does not explain the nature of the "the root covering proper". However, it may originate from the periosteum or epimysium of the muscles that are attached to the transverse process.

The E12 sheet plastination used in this study is advantageous because it enabled us to trace the configuration of the fascia while the structures are conserved in their living position. This can be compared with gross dissections, which disrupt the exact configuration of the fascia like structures in the neck.

The ultrasound technique was very useful in locating the various anatomical structures in the neck. Our findings support the findings reported in other studies, such as (Kapral et al., 2008).

The finding of the multiple origins of the brachial fascial sheath suggests that the single injection or sole-direction of injection is unlikely to achieve an effective plexus block.

These findings may provide an anatomical base for the placement of the needle during the interscalenus block technique. The classic approach described by Winni (1970) of the interscalene block suggests that a single injection into the sheath is sufficient to lead to a successful block. However, our results demonstrate that there are multiple coverings for each cervical nerve root and not a single covering as suggested by Winni (1970). Some reports have suggested that multiple injections might be required in order to improve the usefulness of this technique, particularly in the interscalene approach (Meier and Büttner, 2007). Our data support the use of multiple injections.

However, this study also suggests that a selective blocking to specific part of the plexus may be viable, especially with the aid of the ultrasound techniques.

Moreover, our study suggests that despite the fact the nerve is "nude" in the intervertebral space it is surrounded by an extensive vascular network. This does not support the suggestion of injecting the local anesthetic in the intervertebral space as it will increase the risk of the intravascular spread, intrasubarachnoid or intrasubdural spread, which are the common complications of the brachial plexus block (Winni, 1970).

Although the anatomy of the deep layer of the deep cervical fascia is complicated, our findings may provide a preliminary observation of the prevertebral fascia. Our results suggest that the prevertebral fascia may not be a single layer. A future research project will examine this hypothesis next year.

Conclusions:-

Regional anesthesia of the brachial plexus block is the desired method for upper limb and shoulder surgeries. The anatomy of the brachial plexus sheath has been a centre of debate in clinical anesthesiology. In order to improve various approaches of the brachial plexus block it is essential to know the exact anatomy of the brachial plexus sheath.

This study, undertaking cadaveric gross anatomical dissection and E12 sheet plastination examination found that the brachial plexus sheath has multiple origins.

The nature of the nerve root proper is yet to be determined. The nerve root in the intervertebral space appears without a fascial structure. It is usually in close contact with the vertebral artery and surrounded by a rich vascular structure.

This research suggests that that the precise placement of the local anesthetic is important to achieve effective local blocking of the plexus and the injection of local anaesthetics into the intervertebral space is not recommended.

Acknowledgments:-
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Mr. Matthew Pollard and Mr. Kunnal Sologar and all of the anatomy post-grads across all levels: for the support, laughter and achievements.

I would like to give my kind regards and special thanks to my supervisor Dr. Ming Zhang. He gave me his support, time and knowledge at all times throughout the year. Also, I would like to give my kind regards to Dr. George Dias for his professionalism and marking my previous essays.

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AppendixA Introduction:-
Over the years, the concept of “plexuses anesthesia” has been a centre of tent in clinical anaesthesiology. This conception was introduced to implement a system of single-injection techniques for blocking all of the main plexuses. These plexuses are cervical, brachial, lumber and sacral. Moreover, it was based on the observation that all plexuses pass between two muscles and may be enveloped by the facia investing these muscles. Therefore, the needle must penetrate an “interfacial compartment”, and a single injection of a suitable dose of local anesthetic would block the nerves in the extremities. A plexus is a group of nerves. These nerves form a network with the spine to serve one area of the body. (Longnecker et al., 1998-337)

In clinical practice there are two types of anesthesia: general and regional (local) anesthesia. Hence, the brachial plexus block is a part of the regional methods that is preformed to block the nerves in the upper extremities during surgery.

Generally, general anesthesia is expensive and causes more complications to the patient than the local methods. Therefore, the anaesthetists have determent four main techniques for brachial plexus block. These are: the interscalene, supraclavicular, infraclavicular and axillary techniques. (Longnecker et al., 1998)

Most nerves in the upper limb arise from the brachial plexus. The nerves of the brachial plexus are formed by the union of the ventral rami of the fifth cervical spinal nerves (C5) through the thoracic (T1) nerves. These are called the roots of the brachial plexus. After these roots pass between the middle and the anterior scalene muscles they unite to form three trunks. The superior trunk is formed by the fusion of C5 and C6 roots. The middle trunk is continuous with the C7 root. The inferior trunk is formed by the fusion of C8 and T1 roots. (Morgan et al., 2006)

Figure1 illustrates the anatomy of the brachial plexuses further. (Morgan et al., 2006)
Figure 8: The AnatomyoftheBrachial plexus(Morgan etal.,2006)

The anterior scalene muscle is attached to posterior tubercle of the upper cervical vertebrae, and travels downward to reach the first rib and inserts on the rib in front of the subclavian artery. However, the middle scalene muscle is connected to the posterior tubercle of the upper cervical vertebrae. Moreover, it inserts on the first rib behind the trunks. Therefore, these two muscles enclose the roots and the trunks of the brachial plexus. Moreover, these muscles are surrounded by a sheath whish is a part of the prevertebral facia. Thus, this sheath forms a perivascular space that extends from the intervertebral foramina to the distal axially. This means that in order to provide efficient block to the entire brachial plexus, a single injection of the drug in the sheath is enough. What one must also consider is that this effect is dependent on the volume of the drug and the level of injection administered in that area (Longnecker et al., 1998).

For the purpose of this review these techniques will be discussed further. For each technique the anatomical bases, approaches, indications, post operative complications, advantages and disadvantages will be considered.

The reason for this essay is to give an overview of the different methods that had been used to block the brachial plexuses. Thus, this might help the clinicians in understanding the problems associated with theses techniques (Cornish, 2008). Furthermore, in conjunction with my paper "The Anatomy of the cervical fascia: view and clinical importance", this might help the anesthetists to improve regional anesthesia of the brachial plexuses under the correct knowledge of the anatomy of the cervical fascia, especially the brachial plexus sheath.

The Interscalenebrachialplexus block:-
Figure 9: Interscalene Block(Morgan etal.,2006)

Anatomical bases:-
This method is based on the palpation of the interscalene groove. The interscalene groove is located at the level of the cricoid cartilage and between the middle scalene and anterior scalene muscles. The trunks are the main target for the needle. The needle must enter the brachial plexus sheath to elicit a paresthesia. (Morgan et al., 2006).

Indications:-
The main indications for interscalene block (ISB) are the shoulder and upper arm surgeries, such as acromioplasty and rotator cuff repair (Childs, 2002). Local anesthetic administered by this method spreads from the roots of the BP to the upper dermatomes of the brachial plexus and its upper trunk. Moreover, it may be indicated when shoulder dislocation reduction is necessary (Meier and Büttner, 2007).

The technique:-
There are many approaches for this method that have developed over the years. The first recorded ISB block was preformed by July Etienne in 1925 (Borgeat, 2006). Then, in 1970 Winni conducted the next improvement of this method (Winnie, 1970). The land marks used in his technique are the sternocleidomastoid, the level of C6, the anterior scalene muscle. The level of the C6 is determent by a horizontal line drawn laterally from cricoids cartilage. To determine the sternocleidomastoid the head is slightly turned to the contralateral side of the injection. The patient is asked to elevate the head slightly. This will cause the clavicular head of the muscle to be visualised clearly. Then, the index finger must be placed behind (lateral) to the sternocleidomastoid muscle. The finger now lies on the anterior scalene muscles. When the finger is moved laterally to the lateral edge of this muscle the interscalene groove of rib 1 is reached. To palpate the interscalene groove the middle and the index fingers are positioned along the cricoid line in the groove. Then, a 22-gauge 1.5-inch needle is introduced between them in a direction perpendicular to the skin and advanced slowly in medial, dorsal and caudal directions until paresthesia is evident. The depth of injection where the paresthesia is elicited was not mentioned in his work. The volume of local

anesthetic (eg.0.5% Ropivacaine) that can be injected ranges between 20-40 ml. Figure 2 demonstrates the clinical application of the interscalene block. (Morgan et al., 2006)

Moreover, Winni's approach was a subject for further modification by other clinicians. For example, Meier in his work (Meier et al., 1997) changed the direction of the needle from more cephalad than that described by Winni. In his work, he appointed 91 patients with rheumatoid arthritis to have an open shoulder operation. This modification allowed the entry of the catheter through the junction between the

medial and lateral third of the clavicle. In his approach the patient lies supine and the head is turned to the opposite side of the injection. The scalenus anterior muscle is palpated posterior to the sternocleidomastoid. The interscalene groove is palpated after sliding the fingers laterally over the sternocleidomastoid. A 22-gauge needle is inserted in the groove. The direction of the needle follows the course of the interscalene groove (lateral, caudal, dorsal). The needle should target the distal end of the interscalene groove lateral to the subclavian artery. The needle can get to the brachial plexus at depth of 2.5cm to maximum of 5cm. The nerve stimulator should be used in this technique in order to correct the position of the needle. For example, if the diaphragm twinges (motor response of the phrenic nerve stimulation) the needle is far medially and forward and it should be repositioned backward and laterally. This technique can be established as "single-shot" or as continues technique (Meier and Büttner, 2007).

The advantages:-

Meier reported that 97% of the patients were satisfied with his approach. Therefore, the modified approach by Meier might be very suitable for catheter insertion (Meier et al., 1997). The catheter can be inserted easily after injecting some local anaesthetic. During insertion the catheter should be ahead in position to the needle tip but not more than 3-4 cm (Meier and Büttner, 2007). Nowadays, the interscalene catheter is acknowledged as suitable standards for postoperative pain therapy after shoulder surgery (Borgeat, 2006).

In addition, the ISB is known to reduce the postoperative pain, nausea and vomiting compared to general anesthesia. The successful rate to produce a block with this method is 93-95 % (Tran et al., 2007).

Perhaps the main advantage of the ISB is to provide a safe block during shoulder and upper arm surgeries without the use of large volumes of local anesthetic. However, this is still debatable. A randomised control trial by Urmey (Urmey and Gloeggler, 1993) suggested that reducing the drug volume from 45 ml to 20 ml did not change the impairment in diaphragmatic movement and forced vital capacity.

Furthermore, this method may provide low incidence rate of short and long term complications (Tran et al., 2007).

The disadvantages:-

Winni's approach may not be suitable for the placement of the catheter because the direction of the needle is perpendicular to the brachial plexus trunks (Borgeat, 2006). Moreover, the direction of the needle of his technique may puncture the vertebral artery or cause subarachnoid puncture. Moreover, interscalene block may not be recommended for patients who already have low lung vital capacity or small lung volumes (Meier and Büttner, 2007).

The complications:-

If the needle positioned too inferiorly to the groove and damaged the cupula or plural cavity, tension pneumothorax may occur (Childs, 2002).

The patient might be at risk of hemidiaphragmatic paresis because of the proximity of the phrenic nerve to the interscalene groove. The incidence of diaphragmatic dysfunction can be up to 100% after the ISB largely due to block of the phrenic nerve (Tran et al., 2007). Furthermore, hoarseness may occur following the ISB due to excessive diffusion of the local anaesthetic to the recurrent laryngeal nerve (Neal et al., 2002). There is a reported frequency of 0.2% for central nervous system toxicity associated with this technique. Furthermore, the lateral approach of this technique may lead to unintentional injections of the local anesthetic into vertebral causing blood toxicity. Moreover, nerve damages were reported in some studies due to needle puncture to the nerves.(Long et al., 2002)

Thesupraclavicular (Subclavian) brachial plexus block:-

Figure 10: Supraclavicular Block(Morgan etal.,2006)

Anatomical bases:-

The brachial plexus runs down between the first rib and the clavicle to go through th axilla. This occurs at the lateral border of the anterior scalene muscle. Moreover, the trunks of the plexus are compacted vertically on top of the first rib posteriorly to the subclavian artery.

The technique:-

This technique is summarised in Figure 3 (Morgan et al., 2006).

This classical approach of the supraclavicular block technique was done by Kulenkampff in 1912 (Kulenkampff, 1912). However, Winni and Collins have modified this technique later (Winnie and Collins, 1964), which was named as subclavian perivascular technique. Unlike the classical approach, the direction of the needle is caudal and away from the pleural cupula.

This technique included that the patient is in the dorsal recumbent position. The patient is asked to turn his head slightly to the contralateral side and try to reach his/her knee with the hand. Then, the level of the C6 and the clavicular head of the sternocleidomastoid must be identified. After that, the index finger moved laterally across the anterior scalene muscle. Then the interscalene groove will be palpated. Moreover, the subclavian artery will be palpated inferiorly to the groove. Then a 1.5 inch, 22 gauge needle is inserted above the pulse and directed caudally at flat angle against the skin. Then the needle is advanced slowly until the click is felt and muscle contraction of the forearm is noted (Morgan et al., 2006). Nowadays, this technique can be also done with nerve stimulator to confirm paresthesia (Bollini et al., 2006). The stimulator voltage must decrease to 0.2mA (before the injection (Bigeleisen, 2003). Then, 25-30 ml of local anesthetic (Lidocaine, or Bupivacaine) is injected in this area. It was indicated that Lidocaine has faster onset and lower failure rates than Bupivacaine (Neal et al., 2002).

Indications:-

The indications for the supraclavicular block (SCB) are operations of the forearm, elbow, wrist and hands. In this method the needle is targeted to the trunks or the proximal division of the brachial plexus. The brachial plexus exists most abundantly at the trunk level or the proximal division. (Winni et al., 1997)

The advantages:-

It was suggested that this method is the most reliable for upper extremity surgery because it provides short latency (Brown et al., 1993). However, confirmatory data are not available. Moreover, an efficacious block can be achieved by smaller volumes (25-30) ml of local anesthetic compared with the interscalene and axillary method (Bollini et al., 2006). This method may have a fewer side effects than the ISB. SCB has less incidence of hemidiaphragmatic paresis than ISB with 14% to 86% respectively and not associated with pulmonary function changes (Neal et al., 1998).

Disadvantages and complications:-

SCB may be not suitable for outpatients. This procedure needs to be done by more experienced hands. While using this technique the determination of the landmark in obese patients might be difficult. (Brown et al., 1993)

Perhaps, the most serious complication of SCB is pneumothorax. The incidence of pneumothorax is 0.5 to 6.1%. This is considered as high percentage in clinical practice. Moreover, the risk for arterial puncture and haematomas are 25% and 20% respectively. (Neal et al., 2002)

The Infraclavicular technique:-

Figure 11:

The Infraclavicular Approach (classic approach).(Morgan etal.,2006)

Anatomical b:-

At the level of the first rib the brachial plexus continues to enter the axilla. The trunks are divided into six divisions and then reform into three cords in the axilla. These cords are named by the lateral, medial and posterior cords. These cords were named according to their position with subclavian artery. A point worthy of mention is that the musculocutaneous, the axillary and the median nerves are not within the axillary sheath, because they leave the neurovascular bundle at the level of the coracoid process. The cords of the plexus are usually located at a depth of 5 cm. (Morgan et al., 2006).

Indications:-

The infraclavicular block (ICB) is a useful technique for providing regional anesthesia for the upper extremity during surgeries on the hand, wrist, forearm, elbow and distal third of the arm (Monkowski and Vitale, 2006). Moreover, the modified approach of ICB can be conductive for placement of catheter for post operative analgesia and continues block (Borgeat et al., 2001). Furthermore, in emergency situations ICB might provide a better alternative solution for patients who cannot abduct their arm due to pain. If the interscalene block technique failed to block the ulnar nerve then the ICB would be another option in this case. (Rodríguez et al., 1998)

The technique:-

The technique is illustrated by figure 4 (Morgan et al., 2006).

The ICB can be categorised according to the position of the needle (Monkowski and Vitale, 2006).There are two types of this technique: the lateral and medial approach. The lateral approach (entry site: pericoracoid) which was originally described in 1981 by Whiffler (Whiffler, 1981) in (Crews et al., 2007). This became the most popular approach because the coracoid process was easy to identify as a land mark even in obese patients (Monkowski and Vitale, 2006). This approach was further adjusted by Wilson to reduce the risk of penetrating the thoracic cavity (Wilson et al., 1998).

In Wihffler's classic approach (Whiffler, 1981) the patient lied supine and the head is turned to the opposite side. The arm was abducted 45 degrees from the chest wall. The relevant shoulder was depressed. The clavicle and the coracoid process was identified and marked with a pen. The subclavian artery was palpated at the midpoint of the clavicle. The artery was traced laterally until it vanished under the clavicle. This area was also marked with pen. The axillary artery was palpated with the index finger in the axilla. The thumb was positioned at the anterior chest wall. With a 21-gauge 51ml needle attached to 20 ml syringe the skin is punctured inferiomedial to the coracoid process. After aspiration, a 12 ml of local anesthetic (2% Lignocaine) was injected at that point. This was repeated twice. The X-ray was used to visualize the distribution of the drug. (Whiffler, 1981)

However, the modified work by Wilson in 1998 included that the patient arm is in neutral position. The coracoid process was identified and marked. Then, two centimeters medial and caudal from the coracoid process, a 100mm, 22-gauge needle is inserted perpendicular to the table until a motor response is achieved (flexion or extension of the wrist) with 0.5 intensity or less is obtained. The needle must be always directed to the lateral direction. After a negative aspiration of blood and fade of motor activity 30-40mL of local anesthetic can be delivered. (Wilson et al., 1998)

In 2005 the coracoid approach was altered by (Minville et al., 2005) by adding double stimulation instead of single injection. It is noted that the double stimulation technique can be the optimal choice for ICB (Tran et al., 2007). In the double stimulation technique the patient receives two injections in two sites. First, the needle is inserted toward the musculocutaneous nerve. Then, 10 ml of the Lidocaine 1.5% is injected in the area. After that, the needle is withdrawn 1 or 2cm and reinserted medially and posteriorly towards the main trunk (Minville et al., 2005).

Yet despite these different improvements it was suggested that the lateral coracoid approach may cause difficulties for catheter insertion. Therefore, the medial approach of ICB was conducted by Raj (Raj, 1997). His approach was manipulated later by Borgeat to provide an easy way to insert the catheter. (Borgeat et al., 2001)
The advantages of ICB:

Despite the fact that many land-marks have been modified for ICB, there were no randomized control trials that have proven the dominance of one another (Tran et al., 2007). The ICB provide a block with the arm in any position. It also allows an effective block for all the three cords of the brachial plexus and thus producing a sufficient blockade of all its terminal nerves (Whiffler, 1981). The land marks in this technique are easy to learn. However, because of the difficulties in determining land marks in obese patient it was suggested that (Sandhu and Capan, 2002). Applying multiple injections or double stimulation approach for the ICB resulted in higher success rates than single stimulation. In addition, using ultrasound as a guide for needle insertion reduces the block onset time and decrease the dose of local anesthetic (Koscielniak-Nielsen, 2008).

Moreover, unlike Wilson's approach, Borgeat's approach allowed the insertion of the catheters for postoperative analgesia and continuous analgesia. This is because the direction of the needle was tangential to the cord (Monkowski and Vitale, 2006). The disadvantages and complications:

One of the disadvantages of Borgeat's approach is that the position of the patient's arm may be painful especially for patients with injured limbs (Monkowski and Vitale, 2006). In regards to the complications of the ICB, pneumothorax has been reported in some studies. The reported incidences varied between 0.3% and 6% (Crews et al., 2007), depending on the block technique. However, it was noted that pneumothorax may rarely occur with ICB (Neal et al., 2002). Moreover, due to phrenic nerve paresis, acute respiratory insufficiency may occur with this technique (Heid et al., 2006). Horner syndrome was also reported with vertical ICB. The incidence was between 1% and 6.9% with this approach (Meier and Büttner, 2007). Furthermore, the medial approach presented with higher incidence of vascular puncture than the lateral approach. Nerve damage can result from this approach as well. However, this can be reduced by nerve stimulator (Monkowski and Vitale, 2006).

The Axillary technique:-

Figure 12: Location ofthe injection in theaxillary blocktechnique (Brown,2006)

Anatomical bases:-

Figure 5 illustrates the location of the needle in the axilla (Brown, 2006). The axillary block (AXB) is usually performed by one of the procedures that use the axillary artery as a starting point. The axillary artery originates from the subclavian artery. At the area under the clavicle the subclavian artery becomes the axillary artery. Also, at this stage the cords of the brachial plexus divide into two divisions: the anterior and the posterior divisions. The terminal branches are formed from the cords at the level of the lateral border of the pectorals minor muscle. Moreover, the musculocutaneous is not contained within the axillary sheath. However, it lies within the coracobrachialis once it leaves the axilla. (Morgan et al., 2006)

Indications:-

The AXB is very effective for surgical procedures distal to the elbow, hand, wrist and forearm. Excellent anesthesia and analgesia can be also achieved at the elbow region by this method (Schroeder et al., 1996). Continuous axillary block might be suitable for post operative pain therapy and treatment of chronic pain states (post amputation pain (Grant et al., 2001). Moreover, this technique has minimal impact on respiratory mechanism, making it attractive when respiratory status impaired (Schroeder et al., 1996).

The technique:

The AXB was originally conducted by Hirschel in 1911(Brockway and Wildsmith, 1990). Many modifications for his approach were conducted after that. Moreover, this technique can be applied by various approaches. These are: the transarterial injection (Cocking et al., 1987), elicitation of paresthesia and nerve stimulator techniques (Baranowski and Pither, 1990; Sia et al., 2000). There are many other approaches, such as multicompartmental approach and perivascular technique (Neal et al., 2002). In the transarterial technique the patient is spine and the arm is abducted. The elbow is flexed at 90 degrees and externally rotated. The axillary artery pulse is identified high in the axilla. The patients were asked to inform the anaesthetist if they feel any discomfort during the procedure. Then a 22 gauge, 1.5 in needle is inserted slowly or withdrawn until blood aspiration ceases. Then a total of local anesthetic of 40 ml of Lidocaine 1% is injected. A 20 ml of the LA is injected anteriorly to the artery and another 20 ml posterior to the artery. (Morgan et al., 2006)

In the elicitation paresthesia approach the patient position is similar to the above. The only difference in this procedure is that the needle is directed toward the axillary artery to elicit a single or multiple paresthesia. The paresthesia can be elicited in the nerve distribution of the operative area. For example, in the hands the paresthesia for the median, ulnar and redial nerves can be elicited before injection. (Morgan et al., 2006)

In the nerve stimulator technique, a nerve stimulator is used which is attached to the needle. A muscle twitch in the hand is sought. After reducing the stimulation less than 0.5mA and the motor activity faded after 1 ml of LA, a local anesthetic is injected (40 ml). The median, ulnar and radial nerves are usually stimulated in this method. (Bouaziz et al., 1997)

The perivascular technique was first described by Burnham in 1958 (Franco et al., 2008). This was modified by Winni in 1983 (Longnecker et al., 1998). This was carried out as follows: the patient's position is similar to the above techniques. The axillary artery is palpated and traced until disappear under the pectorals major muscles. The index finger is positioned over the pulse. Then an immobile needle, a 1.5 inch and 22gauge, is inserted until a "click" is perceived. Then a 40 ml is injected slowly with 4-5 ml increments with repeated aspiration for blood between increments. If the surgical procedure requires a block to the musculocutaneous nerve, the musculocutaneous nerve can also be blocked separately by injecting 5 to 8 ml into the body of the coracobrachialis muscle. (Longnecker et al., 1998)

The advantages of the AXB:-

This method can provide high rate of successful block compared with ISB and SCB. In (Schroeder et al., 1996) the rates of successful block for AXB, ISB and SCB were 89%, 75% and 78% respectively, with P value (0,025).

Furthermore, multiple stimulation approach could be more superior to single stimulation approach (Tran et al., 2007). In (Sia and Bartoli, 2001) 81 patients were randomly selected for either triple stimulation AXB or quadruple injection. The triple technique caused less procedure-related pain compared with the quadruple stimulation (visual analogue score = 8 +12 vs. 13+2 mm) respectively (P=0.01).

Therefore, the triple stimulation technique can be the best approach. However, facial clicks, transarterial injection, elicitation of paresthesia and single nerve stimulation have similar effectiveness (Tran et al., 2007).

Furthermore, AXB may have low side effects rate. The block of the recurrent laryngeal nerve and the phrenic nerve are unlikely (Brockway and Wildsmith, 1990).

The disadvantages and complications:-

It has been noted that the elicitation of paresthesia may increase the incidence of post operative neuropathy. Slander and college (Selander et al., 1977) found that eight cases of neuropathy were found in the paresthesia group and two cases in the transarterial group. This was out of ten cases in total. However, there results were not statically significant (no information about P value). Winni, on the other hand, found a significant relationship between paresthesia and neuropathy (Winnie, 1995).

One of the disadvantages of this technique is that it does not usually block the musculocutaneous nerve and may need a separate injection in the body of the coracobrachialis muscle (Morgan et al., 2006).

Summary of the four main techniques:-

Every technique has its own anatomical basis, approaches, indications, complications, advantages and disadvantages. This is summarized in Table 1 below.

Technique	Anatomy basis	Approach	Indications	Advantages	Disadvantages	Complications
ISB	□ Inter scalene groove □ Cricoid cartilage (C6) □ Anterior and middle scalene muscles	□ Palpation of the groove □ 1.5 inch needle □ Dorsal, medial and caudal	□ Shoulder and upper arm surgeries □ Shoulder dislocation reduction	□ Low complications □ □ □ □ □ □ □ □ atheter insertion □ Reduce post operative pain	□ Patients with low lung capacities □ Winni's approach not suitable for catheter	□ Tension pneumothorax □ CNS toxicity □ Intravascular injection (vertebral artery) □ Nerve injury
SCB	□ The brachial plexus is	□ Needle is	□ Fore arm,	□ Short latency □ Fewer	□ Out patients □	□ Pneumothorax □ Arterial

	abundant at the trunk level or proximal divisions	always caudal □ Nerve stimulator used and reduced to 0.2mv	elbow, wrist and hands operations	negative effects □□□□□□□□□ maller drug volumes	Needs experienced hands	puncture □ Haematomas
ICB	□ The targeted area is the cords □ Cords in axilla	□ Needle targeted inferiomedial to the coracoid process	□ Emergency cases □ Surgeries in the distal upper arm	□ Efficient block for the musculocutaneo us nerve □ Higher success rate with double stimulation □ Rare incidence of pneumothorax	□ Painful for injured limb □ May not be suitable for low lung capacities	□ Horner syndrome □□□□□□□□□ Nerve damage □□□□□□□□□ Phrenic nerve paresis
AXB	□ The axillary artery originating from the subclavian artery □ Under the clavicle	□ Transarterial injection □ Elicitation of paresthesia □ Nerve stimulation	□ Continuous axillary block □ Low impact on respiratory mechanism	□ Higher successful block compared with ISB and SCB □ Low side effects rates eg phrenic nerve damage	□ Not suitable for blocking the musculocutaneous nerve	□ Elicitation of paresthesia approach may increase incidence of neuropathy

The interscalene technique is based on locating the interscalene groove. Winni method's included injecting a Local anesthetic in the area between the anterior scalene muscle and middle scalene muscle, targeting the trunks of the BP. This technique is usually indicated for surgeries at the shoulder and upper extremity.

This method should provide an effective block with small volume. The incidence of pneumothorax in this technique is high. Thus, ISB may not be suitable for patients with abnormal lung function test.

The classical approach for the supraclavicular technique was based on the position of the nerves in the axilla between the clavicle and the first rib. This procedure is indicated for shoulder and upper limbs surgeries similar to ISB. However, the injection is made caudal and away from the cupula. This technique can be more reliable than the ISB since it has fewer side effects. However, the incidence of pneumothorax can be higher in this method than the previous.

The infraclavicular block technique is based on locating the cord of the BP and injecting them according to their position with subclavian artery. One of the indications of this approach is providing fast analgesia to a patient in emergency situation. A big advantage of this method is that it can provide an effective block regardless to the position of the arm. Like the previous methods, there are complications for ICB. However, the incidence of pneumothorax was rarely noted in this method (Tran et al., 2007).

In the axillary method, the major anatomical base of this method is to determine the axillary artery pulse as a starting point. This method has many approaches, such as transarterial, perivascular, nerve stimulating and paresthesia seeking technique. The AXB has a greater success rate than ISB and SCB. However, the disadvantage of this method is that it may increase the incidence of post operative neuropathy. A point worthy to mention is that the efficacy of the using the transarterial, perivascular, paresthesia seeking and nerve stimulation methods were similar. Moreover, the triple stimulation technique might be the best approach for AXB (Neal et al., 2002; Tran et al., 2007).

Conclusion:-

Brachial plexus anesthesia has been a centre of consideration for many years in clinical anesthesiology (Tran et al., 2007). It has been suggested that relationship between cost and clinical outcomes for the regional plexus block were better than general anesthesia (Chan et al., 2001). Brachial plexus block is a regional block to the upper extremities during medical operations. This procedure can be conducted by four main techniques. These are the interscalene, supraclavicular, infraclavicular and axillary technique.

The interscalene, axillary, supra and infraclavicular technique are used currently in clinical practice for upper extremities surgeries.

Recently, it has been proven that the use of ultrasongraphy to guide the needle while injecting the BP may improve the success rate of BP block especially for the interscalene block technique (Kapral et al., 2008) and (Koscielniak-Nielsen, 2008).

Tran (Tran et al., 2007) suggested that most of the randomised control trails that were conducted to determine the best technique of the brachial plexus were limited. However, studies that used new techniques such as ultrasound or cloudiness might be more reliable in recommending the best approach. Furthermore, there are still some debatable issues about the sheath around the brachial plexus. It is believed that the precise understanding of the anatomy of the sheath is vital for developing better blocking techniques and controlling the dynamic of the drug injected in the sheath. It has been debated that this sheath may not exist.

Cornish established a radiological study to demonstrate that the nerves are not enclosed by sheath (Cornish and Leaper, 2006). Later, a gross anatomical study was conducted on human cadavers and demonstrated the existence of the sheath (Franco et al., 2008). However, this was debated by Cornish that what had been demonstrated was the prevertebral facia and not the BP sheath (Cornish, 2008). Having said all that, despite the current evidences, perhaps further work is needed in order to determine the best approach for brachial plexus block.

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Appendix B:-

The Anatomy of the Cervical Fascia: views and clinical importance Literature Review for 455 paper
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Introduction:-

For many years, clinicians have been interested in the fasciae of the neck. ‘Fascia’ is a word originating from Latin meaning for band or bandage. Anatomists have used this concept to enclose a range of consistent mesenchymal tissue that envelop around organs or tissue of the body. A Long ago, it was assumed that the fasciae are debris of structures that are not important to the tissue which they are associated. However, fasciae may have clinical and functional interests for surgeons, massage therapist and osteopaths. Fasciae may play a role in understanding muscle action and pain and may be involved in the spread of pus or infection (Benjamin, 2009).

There are at least three different anatomical and histological forms of fasciae. Limbs fasciae have been divided into two parts: the superficial fascia and the deep fascia. The superficial fascia contains blood vessels and nerves that are conveyed to and from the skin. The deep fasciae, however, are dense connective tissue that contains packed collagen fibres. The third type of fasciae is the loose, areolar connective tissue which surrounds the muscles forming the epimysium and endomysium. This type of fascia may endorse independent movement among the neighbouring muscles. Myofibroblasts, elastic and collagen fibres are found in all forms of fascia (Benjamin, 2009).

It has been suggested that the main role of the deep fascia is creating well-defined spaces between muscles called ‘compartments’ or ‘osteofascial’ compartments. Moreover, it may serve as a significant site for the muscle attachment with the bone (ectoskeleton). Furthermore, the deep fascia may bind the skin to the skeleton regulating their transposition during locomotion (Benjamin, 2009).

Another function of the deep fascia is that it acts as a restrictive wrapper for muscles lying deep to them. When these muscles press against this fascia the blood and lymphatic channels are contracted to maintain unidirectional flow towards the heart. This process is called the ‘muscle pump phenomena’. This circulatory function is more important in the lower limb than the upper limb (Benjamin, 2009).

The definition of the fascia was also a centre of debate in the literature. The first edition of the text book Gray’s anatomy (Gray and Carter, 1858) described the fasciae and their associated muscles conjointly. Gray’s mentioned “… as well as from the close connection that exists between the muscles and their investing aponeuroses, that they are considered together” (Gray and Carter, 1858). However, recently, it has been suggested that aponeurosis is a fascial expansion of tendons and not muscles (Benjamin, 2009). Therefore, in my opinion, the connections for the muscles and the aponeuroses between the neighbouring structures are not the same. Thus, the fasciae and muscles are different structures with different connections.

Moreover, the fascia may be arranged in distinctive laminae as described by Johnston and Willis in 1950. However, this was argued by Gardner et al in 1960 that this organisation can be found in cadavers and not in living body (Benjamin, 2009).

Not long ago, further radiological studies on live patients have been conducted in order to get better understanding of the fascia, such as (Cornish and Leaper, 2006; Thompson and Rorie, 1983; Winnie et al., 1979a). However, studies that were conducted on human cadavers were mostly based on dissecting the human tissue. Examples of these studies are (Franco et al., 2008; Partridge et al., 1987b; Patrick, 1940). These studies will be reviewed later in details in following sections.

It is challenging to study the organisation of the connective tissue in cadavers due to the difficulties associated with dissecting out the fascia (Zhang and Lee, 2002). Nowadays, the E12 plastination sheet provides a novel method to explore the connective tissue at microscopic and macroscopic level (Nash et al., 2005a; Zhang and Lee, 2002). This method provides a better dimensional view of the structures being examined in situ (Nash et al., 2005a; Zhang and Lee, 2002).

Over the years, the fasciae of the neck have been an issue of debate. The fasciae of the head and neck were firstly illustrated by Burns in 1811 cited in (Grodinsky and Holyoke, 1938). Since then, however, anatomists and surgeons have explained them unclearly and briefly. This might be due to different observations to the fasciae, causing difficulties for demonstrating a certain definition of these structures. Similar to other parts of the body there are two main divisions of the cervical fascia: the superficial and the deep (Grodinsky and Holyoke, 1938).
Therefore, in this review the anatomy of the cervical fascia will be explored. This will include old and recent anatomical views for the cervical fascia and the methods that had been used to achieve various definitions. Furthermore, the clinical importance of the cervical fascia is discussed in this essay as well. I will mainly focus on the sub divisions of the deep cervical layer: the superficial layer of the deep cervical fascia (investing layer) and the deep layer of the deep cervical fascia (prevertebral fascia) and the brachial plexuses sheath.

The reason for this review was to provide better knowledge of detailed configuration of the cervical fascia. Perhaps this might assist the anesthetists to improve the methods for cervical plexuses block, especially the deep cervical plexus block, and may enable them to understand the dynamic of spread of the injected material in the neck. Moreover, this review may be of use to clinicians for understanding the physiology of neck infections.

Anatomical Views of the Cervical Fascia:-

It has been quoted that “ the cervical fasciae appear in a new form under the pen of each author who attempts to describe them” (Charpy, 1912). During the nineteenth century different researchers have studied fasciae of the neck. During this period the cervical fascia was divided into two layers, superficial and deep (Richet, 1857a). Since that time this observation has been used to describe the fasciae in the neck region (Grodinsky and Holyoke, 1938).

In 1938 Gordinsky and Holyoke (1938) concluded that the cervical fascia is formed of the superficial and deep fascia. The deep fascia is divided into three layers: the superficial, middle and deep. In their investigation (Grodinsky and Holyoke, 1938) they dissected 75 adult cadavers and five full term fetuses. The adult cadavers were injected before dissection with gelatine colored by Indian ink. Then, transverse, sagittal and frontal sections were taken from the adults and fetuses. It was noted that fetuses showed the same fascial organisation as adults. This challenges the report made by (Charpy, 1912) that adult fascial pattern is not revealed until after the neonatal period.

At a later time, (Paonessa and Goldstein, 1976) and (Vieira et al., 2008) have reviewed the work by Gordinsky and Holyoke (1938) but did not mention the number of cadavers. Consequently, they have accepted the description of the cervical fascia that was concluded by Gordinsky and Holyoke.

The Anatomy of the Superficial Cervical Fascia:-

In 1858, Henry Gray described the superficial cervical facia as a “thin aponeuroutic lamina, which is hardly demonstrable as a separate membrane” (Gray and Carter, 1858). He also indicated that the platysma, the external jugular vein and some superficial branches of the cervical plexus exists in this fascia.

However, this description was further illustrated by Gordinsky and Holyoke (1938). They also indicated that the superficial fascia is a continuous sheet expanding from the head and neck into the regions of thorax, shoulder and axillae. Moreover, they suggested that the platysma originates from the mandible and inserts into the superficial fascia. This illustration contradicts Gray’s definition of this muscle. Gray stated that “ it arises from the clavicle, acromion and from the fascia covering the upper part of the pectoral, deltoid and trapezius muscles, its fibres proceed obliquely upwards and inwards along the side of the neck to be inserted into the lower jaw” (Gray and Carter, 1858). Moreover, Gordinsky introduced the concept of “space 1” also called “space 1 of Grodinsky” (Paonessa and Goldstein, 1976) which was not observed by Gray. According to Gordinsky, this space exists within the fatty tissue superficial to the platysma and separates between this muscle and the deep fascia (Grodinsky and Holyoke, 1938). Furthermore, Grodinsky added that the superficial fascia is dense around the muscles of the face except in the region of the eye (orbicular is oculi muscles) where it is loose and areolar, allowing fluid buildup in this region (Grodinsky and Holyoke, 1938). It becomes tight, however, where it contains the epicranius muscle in its deeper part (Grodinsky and Holyoke, 1938).

In addition, according to (Paonessa and Goldstein, 1976) the platysma divides space 1 into two compartments, the superficial and the deep. The superficial compartment contains lymphatic channels. The deep compartment contains the external jugular vein and its lymph nodes. The superficial cervical layer is considered to be a barrier for containing oedema and neck infections (Vieira et al., 2008).

The Anatomy of the Deep Cervical Fascia (DCF):-

The first edition of Gray's anatomy book treated the deep cervical fascia (DCF) as a single layer "…..strong fibrous layer, which invests the muscles of the neck and encloses the vessels and nerves. It commences as an extremely thin layer at the back part of the neck, where it is attached to the spinous processes of the cervical vertebrae, and to the ligamentum nuchae; and passing forwards to the posterior border of the Sterno-mastoid muscle, divides into two layers, one of which passes in front of it and the other behind it " (Gray and Carter, 1858). Then, Poulsen in 1886 cited in (Grodinsky and Holyoke, 1938) divided the DCF into two layers. However, the deep fascia was first demonstrated as containing three layers by Tillaux in 1882 cited in (Paonessa and Goldstein, 1976). Tillaux noted that there is a layer enveloping the trachea, esophagus and thyroid gland. This third layer was called the middle layer. Grodinsky and Holyoke in (Grodinsky and Holyoke, 1938) and Levitt in (Levitt, 1976) strongly agree with Tillaux observations. A recent study also confirms this arrangment of three layers of the deep cervical fascia (Vieira et al., 2008). In addition, according to (Grodinsky and Holyoke, 1938) the deep layer of cervical fascia has been described as a prevertebral layer.

Despite all these studies, however, the exact anatomy of the deep cervical fascia was still questionable (Nash et al., 2005b). It is important to mention that most of previous definitions that had been suggested for the deep cervical fascia came from cadaveric studies. According to (Nash et al., 2005a) it is difficult to study the configuration of the connective tissue in cadavers because great difficulties exists in dissecting the fascia. However, according to (Zhang and Lee, 2002) it is possible to trace the aponeroutic or tendon fibres of a muscle. However, it might be difficult to differentiate between the membranous part of the subcutaneous tissue, deep fascia, epimysium and epitendinium (Zhang and Lee, 2002). Histological examination may overcome this problem, but this technique is limited by the size of small sample area (Nash et al., 2005b; Zhang and Lee, 2002). Therefore, structural details of the fascia need to be further investigated.

According to the latest edition of Gray's Anatomy by (Hayes, 2008) the deep cervical fascia divisions are now called: the investing layer, pretracheal and prevertebral fascia. They will be reviewed below.

Superficial layer of the deep cervical fascia (SDF) or the investing layer Meyers suggested that most of observers agreed on the existence of this layer (Meyers, 1950). The superficial layer of the deep cervical fascia (SDF) was described by Gray, in 1858, as the layer that passes in front of the sternocleidomastoid. It was observed that this layer passes across the parotid gland and the masseter muscles. This was shown by (Gray and Carter, 1858) and Juvara in (Grodinsky and Holyoke, 1938). Nevertheless, in 1870, Juvara was the first to discover that this layer splits to envelope the masseter and pterygoid muscle to form a space that was illustrated by Coller and Yglesias (Grodinsky and Holyoke, 1938). This space was called the masticator space (Coller and Yglesias, 1937).

Furthermore, the anatomy of the superficial layer of the deep cervical fascia was demonstrated further by Gordinsky and Holyoke in 1938. According to (Grodinsky and Holyoke, 1938) this layer splits in the midline to form the suprasternal space anteriorly close to the upper border of the sternum. The anterior and posterior ends are attached to the sternum. Moreover, in consonance with Gray's description, the external jugular vein pierces through this layer (Gray and Carter, 1858). However, based on Grodinsky's observation the external jugular vein was embedded in the anterior part of the SDF. Grodinsky also added that this layer attaches posteriorly to the cervical spinal process supported by the nuchal line (Grodinsky and Holyoke, 1938) and (Meyers, 1950). In addition (Paonessa and Goldstein, 1976) stated that this layer covers two muscles, the sternocleidomastoid and trapezius, and two glands, the submandibular and parotid. Despite all these observations of the investing layer of the deep cervical fascia, the previous studies are inconsistent with more recent observations. For example, it was noticed that the superficial surface of the parotid gland was covered by subcutaneous tissue only (Zigiotti et al., 1991), which challenges the observations made by Gray 1858. In (Zigiotti et al., 1991) the author conducted serial sections of ten human fetuses. Moreover, another study conducted by (Johnson et al., 2000) suggested that the nuchal ligament described in Gray's Anatomy and Meyers does not exist. This was concluded by Johnson et al. (2000) after using the E12 plastination technique combined with gross anatomical dissection of eight adult cadavers. They found that there is no direct connection between the cervical vertebrae and the investing layer. Therefore, the existence of the investing layer was questionable. Also, the recent use of combined techniques of E12.

plastination with confocal microscopy has strongly suggested that the investing layer of the deep cervical fascia does not exist (Nash et al., 2005b).

The reasons behind studying the investing layer of the cervical fascia were many:-

Recently, there has been an increased requirement for achieving a successful regional cervical plexus block (Nash et al., 2005b). This technique could be a better option for surgeries like carotid endaterectomy (Suresh and Templeton, 2004) as it is associated with lower morbidity and mortality (Stoneham and Knighton, 1999). Moreover, it was believed that the deep cervical fascia was an impenetrable barrier (Pandit et al., 2003) and therefore influences the guidance and the localisation of the injected drug (Nash et al., 2005b). Furthermore, because of the lack of knowledge of the anatomy of the DCF Nash et al. (2005b) indicated that it was not clear whether the clinicians should place the needle superficial or deep to the investing layer during cervical plexus block.

Another important clinical aspect worth mentioning is neck infections. It is believed that the complex neck anatomy has made early diagnosis of deep neck infections difficult (Vieira et al., 2008). Therefore, understanding the organisation of deep neck space and fascial planes is crucial for managing these infections (Zhang and Lee, 2002). According to (Paonessa and Goldstein, 1976) there are many anatomical points that are important for understanding the anatomy of neck infections. Firstly, infections may spread by direct extension, lymphatic extension and hematogenous spread. Secondly, the fascia is attached to the bone wherever it crosses it. Lastly, the spread of infection takes the path of least resistance. Therefore, the fascia was defined in his opinion as a fibrous connective tissue that invests the muscles of the neck, binding them into functional units and forming planes and potential compartments (Paonessa and Goldstein, 1976). Therefore, Paonessa agrees with the observation made by (Levitt, 1970).

The middle layer of the deep cervical fascia or the pretracheal fascia:-

In the past, the pretracheal fascia was named by different names, such as the 'middle, pretracheal or buccopharyngeal' layer (Grodinsky and Holyoke, 1938). This fascia, however, has been a subject of controversy. According to Grodinsky and Holyoke.

(1983), in 1908, Woolsey indicated to the presence of the linea alba between the middle layer and the superficial layer. However, other observers disagreed with this observation, such as (Charpy, 1912). Furthermore, some reporters described this layer as a thick layer (Richet, 1857b) and others described it as thin (Grodinsky and Holyoke, 1938).

Interestingly, however, in the first edition of Gray's anatomy (Gray and Carter, 1858) this layer was not mentioned nor it was described. In addition, in the recent Gray's anatomy, the 40th edition, the middle layer was described as thin layer that provides fascial sheaths to the thyroid gland, larynx, pharynx, trachea, oesophagus and the infrahyoid strap muscles. It is attached superiorly to the hyoid bone and inferiorly to the and it blends with the investing layer of the deep cervical and with the carotid sheath (Hayes, 2008).

Grodinsky and Holyoke (1938), however, in their original work (Grodinsky and Holyoke, 1938) subdivided the middle layer into three layers: the sternohyoid-omohyoid, the sternothyroid-thyrohyoid and visceral layer. Moreover, he mentioned that the middle layer is attached along the superolateral border of the posterior belly of the omohyoid to the superficial layer of DSF.

In summary, there might be some differences between current ideas on the middle layer and the classic work conducted by Grodinsky and Holyoke (1938).

The deep layer of the deep cervical fascia or the prevertebral fascia:-

The prevertebral layer was called by the deep layer of the deep cervical fascia in the first edition of Gray's anatomy, and it was described as the layer that passes behind the sternocleidomastoid (Gray and Carter, 1858). However, over the years, the description of this layer was very brief and unclear in text books (Cornish, 2008; Cornish and Leaper, 2006). Therefore, we need to review the original studies that illustrated the structure of the prevertebral fascia.

Originally, according to (Grodinsky and Holyoke, 1938) the deepest layer of the cervical fascia was divided into two main subdivisions: the alar fascia and the prevertebral fascia together with its extensions: the scalenus; transversalis and Sibson's fasciae (the prevertebral fascia of the abdomen).

The alar fascia was firstly suggested by Dean (Dean, 1919). He noticed that there is an additional connection between the visceral fascia and the carotid sheath. This observation was later confirmed by (Charpy, 1912; Grodinsky and Holyoke, 1938). According to Grodinsky and Holyoke (1938) the alar fascia extends across the medline posterior to the pahrynx, epsophegus and vesceral fascia, and fuses with the preveterbral facsia at the tip of the transverse process, and extends anterolaterally to contribute to the medial anterior wall of the carotid sheath. Moreover, the alar fascia forms the posterior wall of the retropharyngeal space and the anterior wall of the danger space (Paonessa and Goldstein, 1976). A recent study by (Vieira et al., 2008) suggested that the alar divisions of the deep layer of the deep cervical fascia contribute to the posterior part of the carotid sheath and not the medial part.

Despite all these previous demonstrations for the alar fascia, the 40th edition of Gray's anatomy does not include this fascia in the carotid sheath anatomy (Hayes, 2008).

Similarly, with regards to the prevertebral fascia, this fascia was not included in the earliest editions of Gray's anatomy. Though, according to Grodinsky and Holyoke (1938) this layer lies anterior to the body of the vertebrae. In the neck, it extends laterally to the tips of the transverse processes where it fuses with these processes and with the alar fascia.

Furthermore, it continues as a sheath for the anterior, middle and posterior scalene muscles, attaching to the transverse process medially and coming together laterally. Gordinsky and Holyoke (1938) called this portion of the prevertebral fascia the scalenus fascia. Additionally, he noticed that the scalenus fascia forms a covering for the cords of the brachial plexus that exists between the scalenus anterior and medius muscles and as it passes deep to the clavicle into the axilla it becomes the axillary sheath (Grodinsky and Holyoke, 1938).However, it was observed by (Zhang and Lee, 2002) that the extension of the prevertebral fascia in the axilla was an extension of the subcutaneous tissue.

It might be important to state that the axillary sheath was not demonstrated in the first edition of Gray's Anatomy (Gray and Carter, 1858). However, in the 18th edition of this book (Gray, 1913) the axillary sheath was described as a fibrous tissue enclosing the axillary vein and brachial plexus and continues with the deep cervical fascia. However, the author did not cite the original studies for this description. In the 25th edition (Gray, 1932) the sheath was detailed further : " as the subclavian artery and the brachial nerves emerge from behind the scalenus anterior they carry the prevertebral fascia downward and laterally behind the clavicle to form the axillary sheath. Then Gray adds: "traced laterally, the prevertebral fascia becomes thinner and areolar in character and is lost as a definitive fibrous layer under cover of the trapezius". Interestingly, this definition has not changed since that time (Gray et al., 1973; Hayes, 2008).

The anatomy of the brachial plexus has attracted the interest of clinicians for many years (Burnham, 1958; Cornish and Leaper, 2006; Franco et al., 2008; Partridge et al., 1987a; Thompson and Rorie, 1983; Winnie et al., 1979b). Recent studies by (Cornish, 2008; Cornish and Leaper, 2004; Cornish et al., 2007; Cornish and Leaper, 2006) have questioned the existence of the axillary or the brachial plexus sheath.

Cornish and leaper (2006) in their study argued that there might not be a surrounding:-

tissue around the brachial plexuses. Instead, the brachial plexus may lie in the tissue plane between rigid anatomical structures. This observation was made after viewing computerised tomographic dye images from three patients after injecting them with a dye. Cornish et al. (2007) named this tissue plane "the axillary tunnel. Recently, however, Franco et al. (2008) has demonstrated the presence of brachial sheath after dissecting 11 embalmed cadavers. Yet, Cornish (2008) stated that what has been shown by Franco et al. (2008) was the prevertebral facia and not the brachial plexus sheath.

Perhaps it might be vital to know the correct anatomy of the brachial plexus sheath (Cornish, 2008). Cornish stated that knowing the accurate anatomy of the brachial sheath may effect the placement of the needle for blocking the brachial plexus since that there has been some problems with some brachial plexus techniques (Cornish, 2008; Cornish and Leaper, 2004). It has been thought that the brachial plexus sheath may affect the distribution of the injected local anesthetic in this sheath (Winnie et al., 1979b). Moreover, Cornish et al (Cornish and Leaper, 2004; Cornish et al., 2007).

explained that injecting the drugs by the traditional brachial plexus blocking techniques may limit the spread of the solution into the tunnel which works as an area of resistance.

Summary and Conclusion:-

The concept of fascia has long interested clinicians and anatomists. Until now, there have been some debates around the anatomy of the cervical fascia. Over the past decade the various approaches that were used to reach different conclusions were cadaver dissections, radiological studies and combining of both macroscopic and microscopic techniques such as E12 plastination. It seems that E12 plastination studies are more reliable for knowing the exact organisation of the fascia in the neck. From these studies, it was concluded that the cervical facia is divided into the superficial layer and the deep layer. The superficial layer of is a continuous sheet expanding from the head and neck into the regions of thorax. It forms spaces in the neck that might be important for understanding neck infections physiology. The deep cervical fascia, however, is divided in to the investing layer, pretracheal and prevertebral. However, according to the recent evidences concluded that the investing layer does not exist at all and the deep spaces in the neck are directly connected to the subcutaneous tissue. Furthermore, this feature should be considered in surgeries such as neck endoscopy and carotid endaterectomy. In addition, the brachial plexus sheath may also not exist, however this is still controversial. This anatomical feature is important in order to understand the mechanics of spread of the drug applied by brachial plexus block techniques.

Having said all that, perhaps further work might be need around the structures of the brachial plexus in order t know the exact anatomy of the brachial plexus sheath.

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