The trans-cervical plane (TCP): A new anatomical landmark for minimally invasive neck surgery

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Summary

The currently used subdivisions of the neck are not helpful in neck surgery. In addition, the wide use of minimally invasive neck surgery has made it necessary to find reference points that make these procedures easier and safer. Here, clinical, anatomical and radiological study was undertaken to determine the relationships between the trans-cervical plane (TCP) and important neck structures. One hundred and ninety healthy volunteers were examined to determine the surface anatomy of the TCP together with 17 CT scans on the same plane and, five cadavers were dissected in an attempt to describe the anatomy of the mid-cervical region. The distance between the submental point and the sternal notch was measured, and the important anatomic features at this level were recorded.

The anatomical location of the TCP was confirmed. TCP was opposite to the lower border of thyroid cartilage in 90% of the cases, and in 10% it was at the cricothyroid membrane. The average distance from the submental point to the TCP in the hyperextended neck was (6.5-11.5 cm). In spite of the wide range of variation of the distance between the submental point and sternal notch (13-23 cm), the middle of this distance is constant and often related to important anatomical structures: the junction between the upper 1/3 and lower 2/3 of the thyroid lobes, superior parathyroid, and the body of the 6th cervical vertebra.

It is concluded that the trans-cervical plane is an important landmark in the neck region that enables accurate and rapid localization of the cricothyroid membrane for emergency cricothyroidotomy and the tracheal rings for percutaneous dilatational tracheostomy and provides a reference point to mark skin incisions necessary for minimally invasive neck surgery.

Key words: Cricothyroidotomy – Dilatational tracheostomy – Invasive neck surgery

Introduction

The neck extends anteriorly from the upper surfaces of the clavicles and the manubrium sterni to the lower border of the mandible. The mid-sagittal line divides the neck into symmetrical halves. Each half is subdivided into anterior and posterior triangles according to its respective relation to the sternocleidomastoid muscle. The anterior triangle is further subdivided into smaller triangles by the superior belly of the omohyoid and the bellies of the digastric muscles; the smaller triangles are the muscular, carotid, submental and digastric triangles. On the other hand, the posterior triangle of the neck is subdivided into two triangles by the inferior belly of the omohyoid: the supraclavicular and occipital triangles (Hiatt and Gartner, 2001; Snell, 2000; Moore and Daley, 1999; Berkovitz and Moxham, 1998; Williams et al., 1995). Another system introduced for clinical assessment of the neck structures divides the neck into two areas; midline area within 2 cm

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from the midline and lateral neck area outside the previous one (Polk et al., 1987). A third system introduced by Monson et al. (1969) divides the neck into three zones; the area below an imaginary horizontal line passing just inferior to the cricoid cartilage is zone I; the area above another imaginary line passing through the angles of the mandible is zone III, while zone II is the wide area that lies between these two imaginary lines.

These systems do not provide reference points to the surface anatomy of the important underlying structures or offer any help in placing surgical incisions especially in emergency procedures or minimally invasive neck surgeries. In this paper the relationship of a newly defined anatomical point (TCP) placed at the middle of a distance between the submental point and the sternal notch to gross anatomical structures in healthy volunteers, cadaveric specimens and CT individual images was examined.

Regardless of the length of the neck, the location of the TCP at the middle of a distance between two fixed points is constant. The goal of this study was to describe precisely the location of the TCP with respect to the important underlying natomical structures. The use of such anatomical methods should result in an improved description of neck structures and a more precise approach for neck surgery.

Materials and Methods

Volunteers

One hundred and ninety normal healthy volunteers were included in this study. They were 147 males and 43 females; their average age was 30.7 (range 18-72 years).

While the neck was in the hyperextension position, the inferior border of the mandible was palpated at the mid line as a starting point (submental point) and the distance to the suprasternal notch was measured. An Imaginary line was placed at the center of the previous distance and named the TCP (Fig. 1). Then, the lower border of the thyroid cartilage was palpated and the distances between it and the submental point and the suprasternal notch were measured.

Radiological study

Eighteen high-resolutions CT scans were obtained from patients with no neck pathology and who had never undergone neck surgery. A line was extended from the midpoint between the submental point and the sternal notch posteriorly to the cervical vertebra while the neck was in the hyperextended position; the anatomical position and structures at that level were recorded.

Anatomical study

The necks of five formaldehyde-embalmed bodies were dissected to verify the level of the cricothyroid membrane. Dissection proceeded systemically from superficial to deep layers. All structures seen at each level were recorded and hand drawn.

Results

In all volunteers it was easy to identify the reference points i.e. submental point (felt at the lower border of the mandible at the mid line), thyroid cartilage, cricoid cartilage and the suprasternal notch. In the morphometric study of our volunteers, the distance between the submental point and the suprasternal notch in the hyperextended neck ranged between 13-23 cm, the TCP was placed at the middle of this distance (6.5-11.5 cm). The distance between the submental point and the inferior border of the thyroid cartilage ranged between 7-12 cm. The TCP passed along the inferior border of the thyroid cartilage in 90% of the volunteers and in 10% over the cricothyroid membrane in the hyperextended neck and over the cricothyroid membrane in the anatomical position.

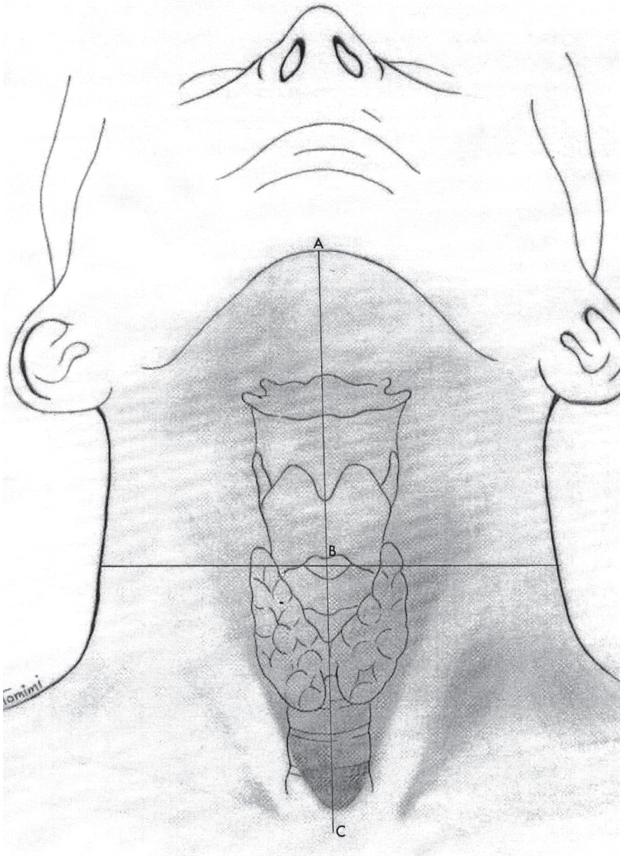

Fig. 1.- Diagram showing reference points and lines; (**A**) submental point, (**B**) lower border of thyroid cartilage, (**C**) sternal notch.

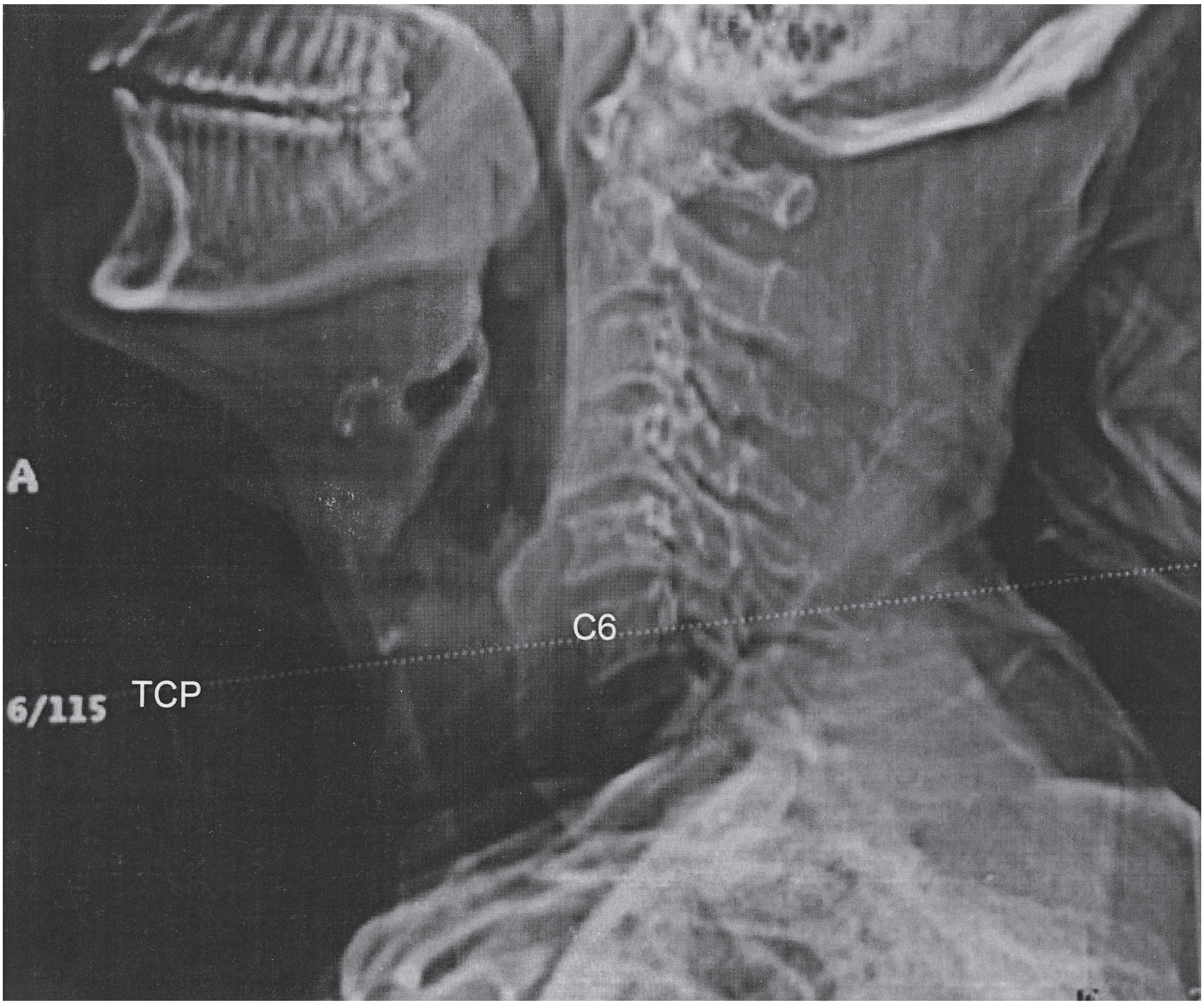

Fig. 2.- Lateral CT scan showing the level of the TCP. THe dotted line is passes through the body of C6.

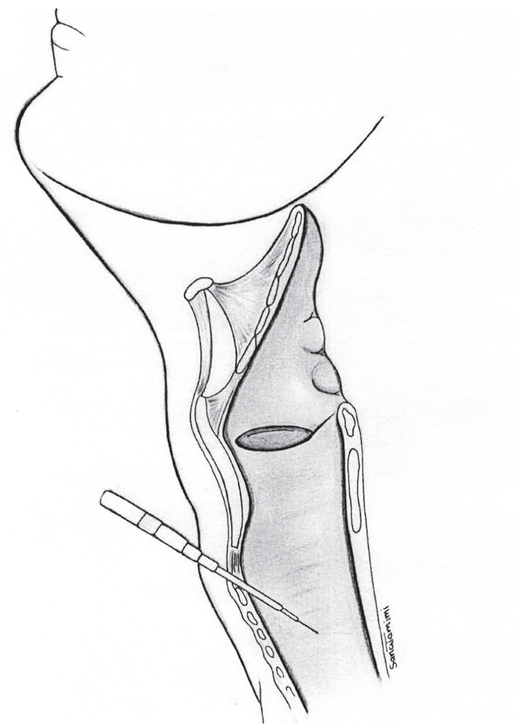

Fig. 3.- Diagram showing a needle in the cricothyroid membrane in criocthyroidotomy.

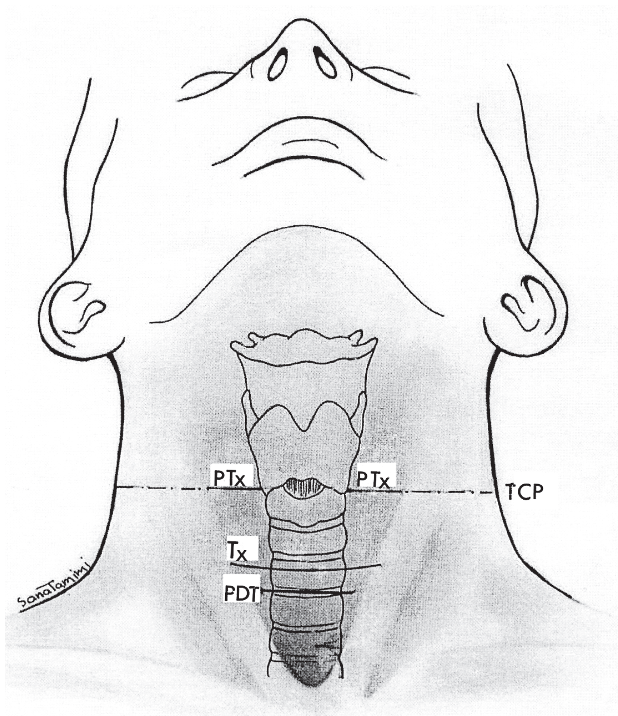

Fig. 4.- Proposed skin incisions for minimally invasive superior parathyroidectomy (PTx), minimally invasive thyroidectomy (Tx) and, percutaneous dilatational tracheostomy (PDT).

Computerized tomography (CT) of the neck in the anatomical position showed that the cricothyroid membrane was at the middle of the distance between the submental point and the sternal notch. Lateral views revealed that this plane passes along the body of the 6^{th} cervical vertebra (Fig. 2).

Dissection showed that the TCP passes through the junction of the upper 1/3 and lower 2/3 of the thyroid lobes. The superior parathyroid glands were found around this plane. The intermediate tendon of the omohyoid muscle was seen just below the level of the cricoid cartilage in two cadavers and below that in the other 3 cases. In all cases, at the level of the 6^{th} cervical vertebra, the inferior thyroid artery arched medially before branching; the vertebral artery entered the foramen transversarium, and the middle cervical ganglion was located on the sides of the vertebral body.

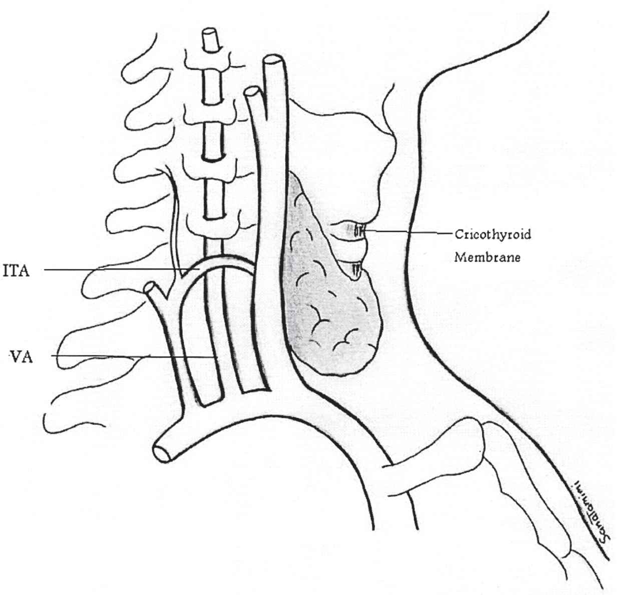

Fig. 5.- Some of the structures seen at the level of C6.

Discussion

Many authors have addressed minimally invasive neck surgery in the outpatient setting and in the context of bedside surgery in the intensive care unit. The technique and outcome of cricothyroidotomy (Jones and Roberts, 2002; Mori et al., 2002; Schroeder, 2000; Warmington et al., 2000), percutaneous dilatational tracheostomy (Carrillo et al., 1997; McHenry et al., 1997; Cobean et al., 1996; Hill et al., 1996) minimally invasive thyroidectomy (Ohgami et al., 2000; Miccoli et al., 2001a; Miccoli et al., 2001b; Lorenz et al., 2001; Miccoli, 2002), and parathyroidectomy (McGreal, 2001; Sackett et al., 2002; Agarwal et al., 2002) are well documented.

One of the most common problems encountered in performing emergency or minimally invasive neck surgery is the difficult anatomical relationships and crowding of the structures in the central neck region. Several different anatomical descriptions of the neck region have been given. One description distinguishes two neck triangles, the anterior, and posterior triangle. According to this system, the neck is devided by the sternocleidomastoid muscle into two triangles and the anterior triangle is further subdivided into several triangles by the omohyoid and the digastric muscles. Another system devides the neck into two regions: midline and lateral neck region. A third system divides the neck into 3 zones. None of these systems provides a reliable antomical landmark that can be used for neck surgery. These systems do not provide reference points to the surface anatomy of the important underlying structures or offer any help in placing surgical incisions, especially in emergency procedures or minimally invasive neck surgeries. Thus, it is mandatory to find another reference point that can be used for surgical neck procedures. In the present study we describe the TCP by using fixed anatomical landmarks -the submental point and the suprasternal notch- as reference points. In humans Both landmarks can be easily identified by palpation. In this study, the distance between the submental point and the sternal notch was 13-23 cm and the TCP was located at the distance (6.5-11.5 cm) in 90% of the volunteers.

Although most of our volunteers were relatively young individuals, with rather obvious anatomical landmarks, the site of the TCP was fairly constant along the lower border of the thyroid cartilage when the distance between submental point and sternal notch was measured in the hyperextended neck. In the anatomical position (midway between extension and flexion), the TCP descends downward close to the cricothyroid membrane level. The site of larynx may vary between individuals (low-lying and high-lying larynx). However, these variations are presumably related to the length of the neck, which does not influence the site were the centeral point was placed.

Anatomically, the level of TCP (the body of C6) represents an important landmark. At this level the inferior thyroid artery curves medially, the middle thyroid vein leaves the thyroid gland, the common carotid artery can be pressed against the carotid tubercle, and the vertebral artery enters the foramen transversarium (Fig. 3). The TCP also marks the location of the middle cervical ganglion (Cobean et al., 1996; Carrillo et al., 1997; Berkovitz and Moxham, 1998; Hiatt and Gartner, 2001; Agarwal et al., 2002). The blood supply of the area below the TCP is from branches of the subclavian artery and the only cranial nerves seen in it are the vagus and the accessory nerves. Branches from the external carotid artery supply the area above the TCP. Also, the TCP passes along the junction of the upper and the middle thirds of the thyroid lobes, where there is the greatest concentration of C cells (Thompson and Vinik, 1983) and the where the superior parathyroid glands are usually located. Therefore, the TCP has practical importance for the surgeon. The intersection between the TCP and the sagittal plane can easily be identified on the patient's neck to perform emergency cricothyroidotomy just below this point (Fig. 4), and approximately 15-20 mm below it percutaneous dilatational tracheostomy can be performed (Fig. 5).

Secondly, the location of the TCP is of a great importance for neck surgeons because it can be used as a guide to plan incisions in this region. The TCP line can be drawn on the patient's neck prior to minimally invasive superior parathyroid surgery. Depending on the location of a superior parathyroid adenoma, a 1-2 cm skin incision on the TCP line can be used to remove the adenoma, and thyroid incisions can also be made at a line approximately 1.5 cm below the TCP line (Fig. 5).

We have examined the precise relationship between the location of the TCP and the important neck structures in humans. Our results confirm the location of the TCP at the lower border of thyroid cartilage, just above the cricothyroid membrane. The TCP can be used as a reference point that provides an accurate and rapid localization of the cricothyroid membrane for emergency procedures, helps mark the skin incisions necessary for minimally invasive neck surgery, and represents the level at which important anatomical structures can be located.

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