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A morphological study of the nerve of Kuntz

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SUMMARY

Hyperhidrosis is an idiopathic disorder of the autonomic nervous system characterized by hyperactivity of the exocrine sweat glands, resulting in excessive palmar, axillary, pedal, craniofacial or whole body sweating. Currently, trans-thoracic endoscopic sympathectomy, consisting of ablation of ganglion or resection of one segment of sympathetic trunk, is the treatment of choice for palmar hyperhidrosis. The important causes of unsuccessful sympathectomy include sympathetic regeneration and alternate sympathetic pathways. The most cited alternate pathway is the nerve of Kuntz. In the present study, the frequency of the nerve of Kuntz was investigated in 46 adult and 10 foetal cadavers. The nerve of Kuntz was found in 42 sides among 112 sides studied. The variants of this nerve observed in the present study were classified according to scheme proposed by Chung et al. (2002) as A, B, C and D types. 13.39% of type A, 11.61% of type B, 8.93% of type C and 3.57% of type D nerve of Kuntz were found in the present study. Studies suggest that the palmar hyperhidrosis is common in Asian population especially women. But as such very few studies on nerve of Kuntz are available from Asia. Today, a great number of thoracoscopic sympathectomies undertaken have redefined the role of alternate neural pathways. Experience of many surgical studies has also demonstrated the need to be aware of the anatomy of the sympathetic chain. Current study assumes importance in keeping the surgeon alert regarding the variations of the sympathetic chain while operating on the local population which can reduce recurrence of palmar hyperhidrosis after a seemingly successful upper limb sympathectomy.

Key words: Hyperhidrosis – Nerve of Kuntz – Sympathectomy – Thoracic sympathetic chain

INTRODUCTION

Hyperhidrosis is a pathologic condition due to an idiopathic disorder of autonomic nervous function, in which exocrine sweat glands have remarkable hyperactivity resulting in excessive palmar, axillary, pedal, craniofacial or whole body sweating (Alex, 2004).

It has been suggested that the pathophysiology of essential hyperhidrosis could be caused by an unexplained localized over-functioning of the sympathetic fibres that pass through the T2 and T3 ganglia (Connolly and de Berker, 2003).

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Palmar hyperhidrosis has a serious impact on professional and social life and may lead to emotional problems in an individual. Axillary hyperhidrosis causes wetness, staining and rotting of clothes, with ensuing social embarrassment (Drott et al., 1993; Lin, 2001).

A variety of nonsurgical treatments such chemotherapy have been used for this condition, but the results have been disappointing and improvements are transient (Stolman, 1987; Shelly et al., 1998; Fredman et al., 2000; Reisfeld et al., 2002).Surgical intervention consists of interrupting the transmission of sympathetic impulses from the lower sympathetic ganglia to the hands (Reisfeld et al., 2002).

Currently, trans-thoracic endoscopic sympathectomy, defined as the ablation of the ganglion or resection of one segment of the sympathetic trunk, is the treatment of choice for palmar hyperhidrosis (Lin, 2001). The important causes of unsuccessful upper limb sympathectomy include sympathetic regeneration and alternate sympathetic pathways. The most cited alternate pathway is the «nerve of Kuntz» (Simmons and Sheehan, 1939; Smithwick, 1940; Singh et al., 1998; Ramsaroop et al., 2001). The nerve of Kuntz was discovered by Albert Kuntz in 1927, a neuroanatomist from the St. Louis University School of Medicine. The nerve of Kuntz is the inconstant intra thoracic ramus between the 2nd intercostal nerve and the ventral ramus of the 1st thoracic nerve, proximal to a point where the latter gives a large branch to the brachial plexus (Ramsaroop et al., 2001).

Kuntz attributed instances of sympathetic recurrences to this neural variant because it afforded an alternate pathway to the brachial plexus following stellate ganglionectomy (Ramsaroop et al., 2001). The reported success rates of trans-thoracic endoscopic sympathectomy are approximately 95%, with low long-term recurrence rates. Knowledge of the anatomy of the nerve of Kuntz is essential for surgeons to be able to excise it in order to further avoid the recurrence of sympathetic activity after sympathectomy (Reisfeld et al., 2002). Palmar hyperhidrosis is considered as common among Asians, especially among women. However, very few studies are available in the literature concerning the frequency of he nerve of Kuntz in Indians (Jit and Mukerjee, 1960). In the present study, an attempt was made to establish the frequency and variants of this neural structure.

Materials and Methods

Data were collected by gross dissection of embalmed dissection-room cadavers of adults of both sex and embalmed full term foetuses. In all, one hundred and twelve sides of 46 adult cadavers (34 males and twelve females, 82 sides), and 10 foetuses (seven males and three females: 20 sides) were used. The adult cadavers were bodies allotted for undergraduate student dissections in the Dept. of Anatomy, St Johns Medical College, Bangalore, and the Sree Siddhartha Medical College, Tumkur.

Following reflection of the anterior wall and evisceration of the thorax, the parietal pleura of the posterior thoracic wall was stripped off and the thoracic sympathetic chain was exposed on either side of the thoracic vertebral column. The 1st intercostal space was cleaned carefully and any nerve cord connecting 2nd and the 1st intercostal nerves was sought. Wherever a ramus connecting the 2nd and 1st intercostal nerve was noted, it was carefully cleaned and the nature of its connection to the 1st thoracic nerve was observed, i.e., whether to the stem of the 1st thoracic nerve, or to the intercostal branch of the 1st thoracic nerve, or to the 1st thoracic sympathetic ganglion, or to the stellate ganglion, or to the interganglionic chain between the 1st and 2nd thoracic sympathetic ganglion was noted down. Depending on the nature of the connection to the 1st intercostal nerve or the sympathetic chain, it was classified as type A, B, C and D, as described by Chung et al. (2002) (see Fig. 1).

The diameter of the stem of the nerve of Kuntz and the distance between the stem of the nerve of Kuntz and the thoracic sympathetic chain were measured to the nearest millimetre using a digital calliper. The results were compared with those from previous studies available in the literature.

Results

Frequency of the nerve of Kuntz (see Table 1): Of the 112 sides of the cadavers examined, a true nerve of Kuntz was only found in 27 cadavers (bilaterally in 15 cases and unilaterally in 12 cases; in all 42 sides out of 112 -37.5%-). No communication between T1 and T2 were found in 12 cadavers bilaterally and in 16 cadavers unilaterally (40/112 -35.71%).

In 30 sides (26.79%) of the cadavers, only a grey ramus communicans between the T2 and T1 ganglia or T2 to the sympathetic chain between T2 and T1 wAs found.

Among the adult cadavers out of 92 sides dissected the nerve of Kuntz was found in 34 sides (36.96%). The nerve of Kuntz was found in significantly higher numbers in adult males than in adult females (males: 18/34; 52.94%; females: n=4/12; 33.33%). Among the full term foetuses (n =10; 20 sides) the nerve of Kuntz was found in three foetuses bilaterally and in two foetuses unilaterally (5/10; 50%).

Diameter of the stem of nerve of Kuntz: The mean diameter of the stem of the nerve of Kuntz among the adult male cadavers was 2.23 ± 1.63 mm (range: 0.93 to 7 mm ; right side 2.58 ± 1.87 mm, left side 2.0 ± 1.486 mm). The mean diameter of the stem of the nerve of Kuntz among the adult female cadavers was 1.03 ± 0.42 mm (range: 0.60 to 5 mm; (right side 0.92±0, left side 1.06 ± 0.503 mm). The diameter of the stem of the nerve of Kuntz among the foetal specimens was very thin and measured less than 1 mm.

Distance of the nerve of Kuntz from the second thoracic ganglion: The mean distance of the nerve of Kuntz from the 2nd thoracic ganglion among adult male cadavers was 7.68 ± 2.32 mm (range: 3 to10.54 mm; mean distance-right side 9.05± 2.145 mm, left side 6.68 ± 1.96 mm). Among the adult female cadavers, the mean distance was 5.93 ± 2.411 mm (range: 4.2 to 9.5 mm; mean distance right side 4.2±0 mm, left side 6.5 ± 2.59 mm). Among the male foetuses the mean distance was 3.62 ± 1. 6 mm (range: 1 to 6 mm; mean distance right side 4.67 ± 1.55 mm, left side 3 ± 1.58 mm). Among the female foetuses: the mean distance was 3.33 ± 1.15 mm (range: 2 to 4 mm; mean distance right side 4 ± 0 mm, left side 3 ± 1.41 mm).

Frequency of the variants of the nerve of Kuntz (see Fig. 2): Table 2 shows frequency of the variants of the nerve of Kuntz in the present

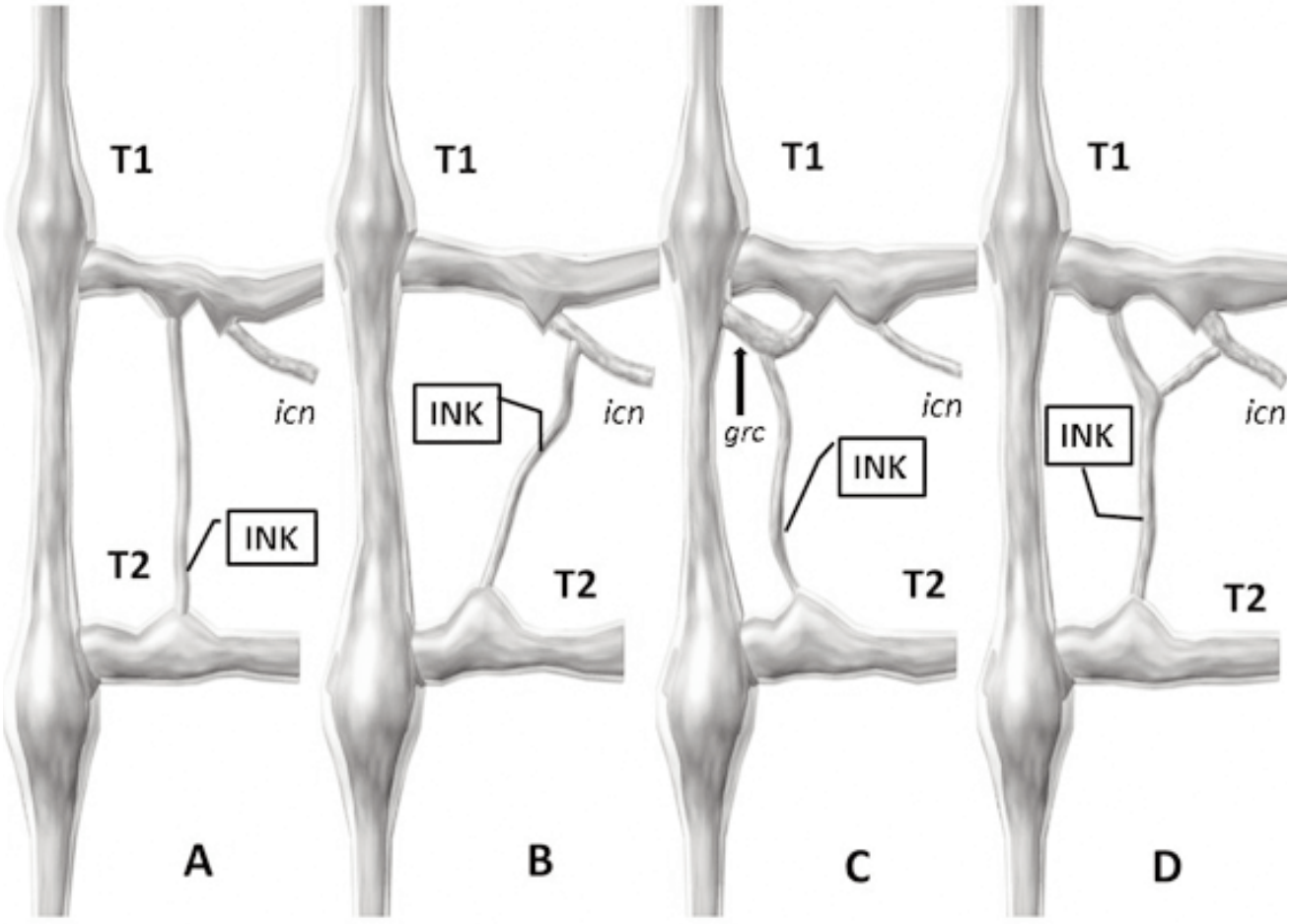

Fig. 1. Diagrams illustrating four variants of the intrathoracic nerve of Kuntz. A- communication between the trunk of T2 and T1; B- communication between trunk of T2 and the intercostal branch of T1; C- communication of T2 with both thoracic sympathetic ganglion and the trunk of the T1 via a ramus communicans; D-communication between T2 and both the trunk of T1 and the intercostal branch of T1. (modified from Chung et al., 2002).

series. The highest frequency was found to be that of the B variant (13/82 sides-15.85%) among the adults. Bilateral symmetry was observed in three adult male cadavers, one each among categories A, B and D. All cases among the female adult cadavers were unilateral.

Among the foetuses, only in eight out of 20 sides was the nerve of Kuntz found: unilaterally in two and bilaterally in three (three of A type and five of C type).

Discussion

Topography of the nerve of Kuntz

Albert Kuntz, a renowned neuroanatomist from the St Louis University School of Medicine, was the first to draw attention in 1927 (Kuntz, 1927) to a variable intrathoracic ramus between the 2nd intercostal nerve and the ventral ramus of the 1st thoracic nerve, proximal to the point where the latter gave off a large branch to the brachial plexus. Kuntz

Table 1. Incidence of Nerve of Kuntz in the present study

Material examined		Bilateral	Unilateral		Total number of sides found
			Right	Left	
Adults: (n-46)	Males (n-34)	12 (24 sides)	2	4	30/68 (44.12%)
	Females (n-12)	0	4	0	4/24(16.67%)
Fetuses: (n-10)	Males (n-7)	2 (4 sides)	1	0	5/14 (35.71%)
	Females (n-3)	1 (2 sides)	0	1	3/6 (50.0%)
Total		15 (30 sides)	7	5	42/112 (37.5%)

Table 2. Incidence of variant patterns of Nerve of Kuntz in the present study

Type →		A	B	C	D
Adults:	Males (34)	1bil;8unil (4R;4L)	1bil;10unil (3R;7L)	0 bil;4unil (3R;1L)	1bil;2unil of left side
	Females (12)	0 bil;2unil (bothR)	0 bil;1unil of right side	0 bil;1unil of left side	0
Adults Total (n=46)		11/46 (23.91%); 12/82sides (14.63%)	12/46 (26.09%); 13/82 sides (15.85%)	5/46 (10.87%); 5/82 sides (06.1%)	3/46 (06.52%); 4/82 sides (04.88%)
Fetuses:	Male (7)	0 bil; 3 unil of right side	—	0 bil; 2 unil of left side	—
	Females (3)	—	—	1 bil;1unil of leftside	—
Total fetuses (10)		3/10 (30.0%); 3/20sides (15.0%)	—	4/10 (40.0%); 5/20 (25.0%) sides	—
Total (n=56/112 sides)		15/112 sides (13.39%)	13/112 sides (11.61%)	10/112sides (8.93%)	4/112 sides (03.57%)

Table 3. Comparative incidence of Nerve of Kuntz in the literature: a) Anatomical studies.

Author/Year/Race	Material studied: no. of specimens	No present (%)	Author/Year/Race	Material studied: no. of specimens	No present (%)
1. Kuntz (1927) (American)	Adult cadavers: n=48	Bil-21;Uni-9 (53.12)	6. Chung et al. (2002) (Korean)	Adult cadavers: n= 39	45sides (57.7)
2. Kirgis and Kuntz (1942) (American)	Adult cadavers: n=44	Bil-26; Uni-14 (75)	7. Singh et al. (2005) (South African)	Adult cadavers: n=20	19 cadavers (92)
3. Jit and Mukerjee (1960) (north Indian)	Adult cadavers: n= 50	Bil-14; Uni-10 (48)	8. Cho, Lee, Sung (2005) (Korean)	Adult cadavers: n=42	50 sides (59.5)
4. Groen et al. (1987) (Netherlands)	Human fetuses: n=6	4 (66.7)	9. Zaidi and Ashraff (2010) (Arabians)	Adult cadavers: n=25	33 sides (66)
5. Ramsaroop et al. (2001) (South African)	Adult cadavers:n=18; Human Fetuses: n=32	46 sides (46)	10. Present study (South Indian)	Adult cadavers: n=46 Human Fetuses: n=10	42 sides (37.5%)

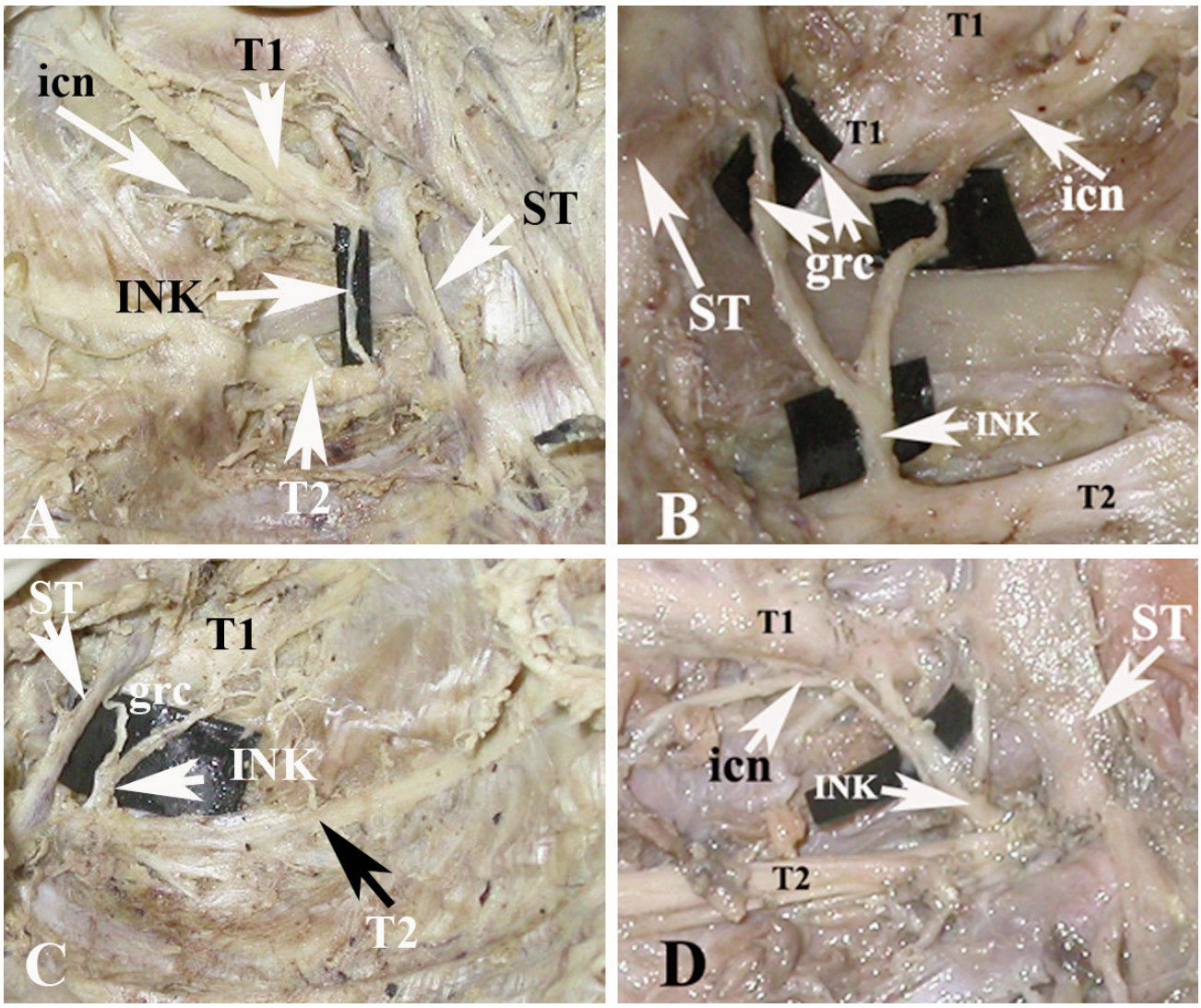

Fig. 2. Photographs of specimens illustrating variants of the intrathoracic nerve of Kuntz observed in the present study: Figs. A, B, C, D illustrate the corresponding A, B, C, and D types of nerve of Kuntz, respectively.

attributed instances of sympathetic recurrence to this neural variant because it afforded an alternative pathway to the brachial plexus following stellate ganglionectomy. Following Kuntz's initial report of this intrathoracic ramus between the 1st and 2nd thoracic ventral rami, anatomists have shown longstanding interest in its frequency and variations (Kirgis, 1941; Kirgis and Kuntz, 1942; Jit and Mukerjee, 1960). For many years much confusion prevailed as regards the identity of the nerve of Kuntz since those authors demonstrated additional connections of the sympathetic chain in the upper three intercostal spaces. Ramsaroop et al. (2001) have insisted that the eponym «nerve of Kuntz» should be restricted only to the ramus joining the 2nd intercostal nerve to T1. In the present study we followed the definition of the «nerve of Kuntz» as proposed by Ramsaroop et al. (2001).

Comparative racial frequency of the nerve of Kuntz

a) Anatomical (cadaveric) studies (see Table 3): The highest frequency has been reported in the cadaveric study of African subjects (Ramsaroop et al., 2001 - 92%). However the number of cases examined was quite small (20 cadavers). The next highest frequency can be seen in an American study by Kirgis (1941) and Kirgis and Kuntz (1942) (75%). The owest frequency (37.5%) is that of present study.

b) The frequency of the nerve of Kuntz according to the surgical literature (see Table 4): The percentage of frequency quoted in the surgical literature is highly variable (0.5% - Dohayan, 1999; 58.06% - Lemmens and Drukker, 1985), but is generally assumed to be 10% (Drott et al., 1993). Lemmens and Drukker (1985) found a constant presence of the nerve of Kuntz in 18 out of 31 patients

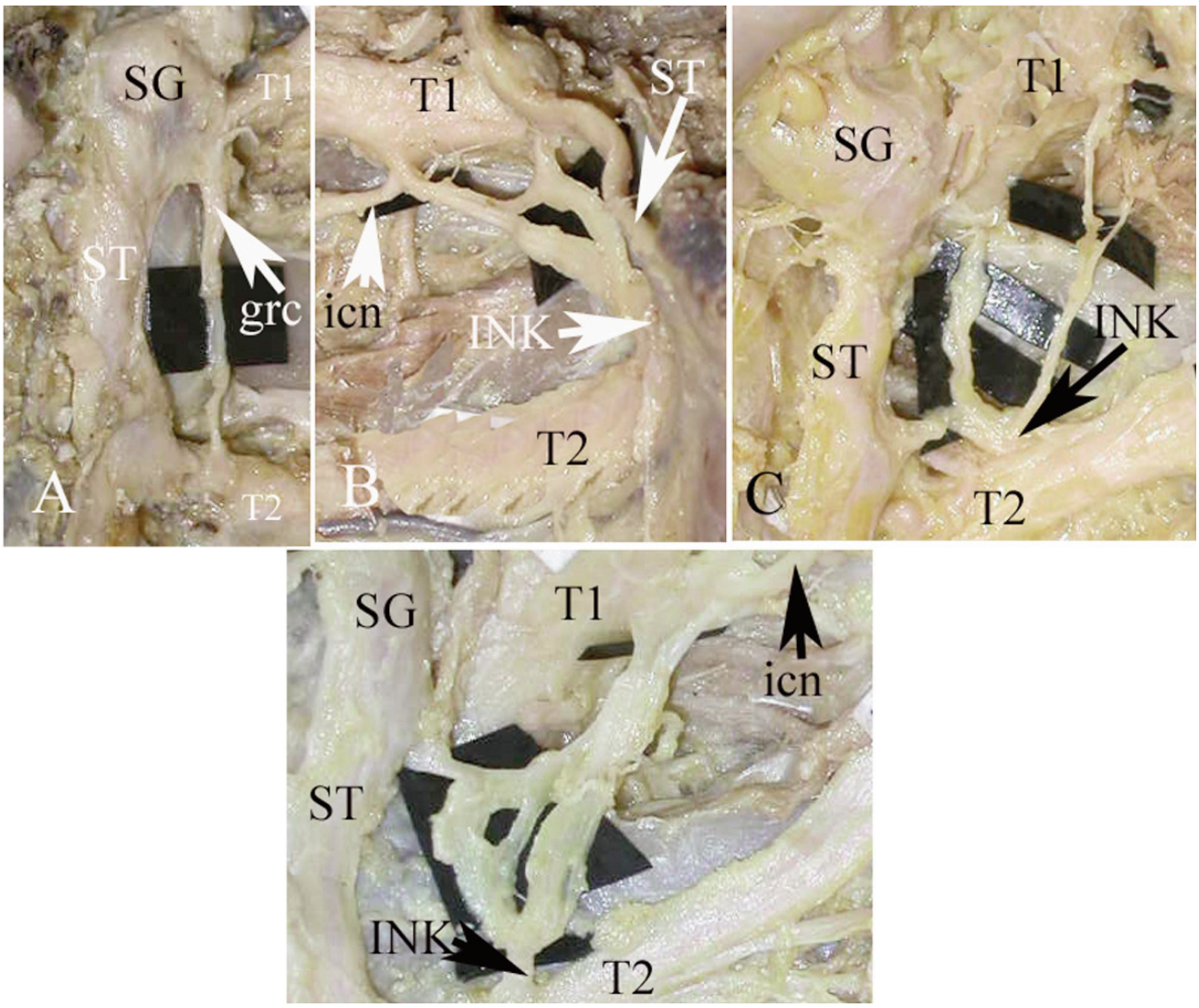

Fig. 3. A: Illustrates a grey ramus communicans between T2 nerve and the stellate ganglion; **B, C and D:** illustrate complex plexiform patterns of nerve of Kuntz observed in the present study formed by anastomosis of the nerve of Kuntz with the grey ramus communicans.

Abbreviations used: **INK-** intrathoracic nerve of Kuntz; **ICN-** Intercostal nerve; ***grc-*** ramus communicans; **SG-** stellate ganglion; **ST-** sympathetic trunk; **T1, T2-** trunks of the 1st and 2nd thoracic nerves.

during an operation known as «thoracodorsal sympathectomy en bloc». As such, there are no reports available in the Indian surgical literature cor comparative purposes.

Foetal studies

Only two other studies have dealt with the frequency of the nerve of Kuntz in foetuses. The study by Ramsaroop et al. (2001) does not clearly state the exact pattern of the frequency of the nerve of Kuntz among foetuses and the results have been quoted along with those of adult cadavers. Groen et al. (1987) found the nerve of Kuntz in four out of six foetuses in their study (66.7%). In the present study, among ten foetuses examined, the «nerve of Kuntz» was found in eight sides (8/20 sides, 40%).

Side and Sex dominance

The studies by Kirgis (1941) and Kirgis and Kuntz (1942) show a high percentage (26% and 21%, respectively) of bilateral frequency. The figures quoted by Jit and Mukerjee (1960) in their study of Punjabee cadavers are higher than those of the above studies (14/50; 28%). Our study shows 26.78 % of bilateral frequency (15/56 cadavers; 30/112 sides). As such, no sex dominance has been mentioned in the anatomical studies available in the literature.

Proximity of the nerve of Kuntz to the T2 ganglion

In the study reported by Ramsaroop et al. (2001) the 2nd ganglion was consistently present and located on the head of the 2nd rib at the costovertebral junction. The distance of the nerve of Kuntz from the 2nd ganglion was

2.3-15.7 mm in adults and 2.1-4.3 mm in foetuses.

In their study of Korean cadavers, Chung et al. (2002) reported an average distance of 7.3 mm of the nerve of the Kuntz from the sympathetic trunk (28.3% between 0-5 mm, 52.2% between 5-10 mm, and 19.5% between 10-15 mm). Cho et al. (2005) reported the farthest horizontal distance of the communicating ramus from the sympathetic chain as 28.5 mm. In the present study, among the adult male cadavers the distance of the nerve of Kuntz was 3-10.54 mm and among the adult females the mean distance was 4.2-19.5 mm.

Diameter of the nerve of Kuntz

The diameter of the nerve of Kuntz in the Korean cadaveric study of Chung et al. (2002) was in the 0.38-3.38 mm range (mean 1.25±0.55mm) and in the study of Arab cadavers by Zaidi and Ashraf (2010) it was 1.32±0.10 on the left side and 1.29±0.12 on the right side. In the present study, the diameter of the nerve of Kuntz among the adult male cadavers was 0.93-7 mm and among the adult female cadavers the diameter was 0.60-5 mm.

Comparative frequency of the variant forms of the nerve of Kuntz (see Table 5)

In their study, Ramsaroop et al. (2001) proposed an anatomical classification of the variations of the nerve of Kuntz. Chung et al. (2002) described a modified method of identifying anatomic variations of the nerve of Kuntz. The nerve of Kuntz was classified in their study into four types according to the connecting nerves: type A, connection from the T2 to the T1 nerve; type B, connection from the T2 to the first intercostal nerve; type C, the nerve of Kuntz originated from the T2 nerve and was connected to the ramus communicans between the stellate ganglion and the T1 nerve; and type D, the nerve of Kuntz was branched and connected from the T2 nerve to the T1 nerve and the first intercostal nerve. In the present study we found the classification proposed by Chung et al. (2002) as simple and convenient, and hence we followed their method (see Fig. 1). Tables 2 and 5 show the frequency of the variants of the nerve of Kuntz in the present study and compare the frequency of the variants with those reported in other studies available in the literature.

Table 4. Comparative incidence of Nerve of Kuntz in the literature: b) Surgical studies.

Sl no.	Author /Year	No. of cases studied	No present (%)
1.	Lemmens and Drukker (1985)	31	18 (58.06)
2.	Hsu, Chen, Hsia, Shai (1998)	20	1(5)
3.	Dohayan (1999)	50	1(0.5)
4.	Lin (2001)	16	3(18.8)
5.	Han, Kenny, Dickman (2002)	83	(Less than 5)
6.	Wang, Sun, Lin, Chen (2002)	70	7(10)

Table 5. Comparison of incidence of the variant forms of the Nerve of the Kuntz.

Author /Year	No. of sides studied	Type			
		A	B	B	C
Ramsaroop et al. (2001)	100 sides	27%	12%	7%	—
Chung et al. (2002)	78 sides	47%	12.1%	7.1%	1.5%
Zaidi and Ashraff (2010)	50 sides	26.3%	15.7%	31.6%	26.4%
Present study	112 sides	13.39%	11.61%	8.93%	3.57%

Variations of the nerve of Kuntz as observed in the present study (see Figs. 2 and 3)

On the whole, type A was found to have the highest frequency (13.39 %), followed by type B (11.61%).

In many specimens, a grey ramus communicans anastomosed with the nerve of Kuntz, resulting in a complex plexiform arrangement. In the study reported by Chung et al. (2002), type A showed the highest frequency (47%) followed by type B (12.1%), type C (7.1%) and type D (1.5%). Among the foetal specimens in the present study, out of eight sides having the nerve of Kuntz type A was present in three sides (37.5%) and type C was noted in five sides (62.5%).

Importance of the nerve of Kuntz during sympathectomy and in cases of recurrence of hyperhidrosis

One of the reasons quoted for the persistence of sympathetic activity after sympathectomy is invariably a result of the failure to appreciate an alternative anatomical pathway at the time of surgery, i.e., the nerve of Kuntz. This, and similar alternate pathways, may not be recognized during standard sympathectomy and may subsequently bypass the sympathetic chain and reach the brachial plexus directly and take over the sympathetic supply to the upper limb (Singh et al., 1998).

Video-assisted thoracoscopic resympathecotomy is an effective and safe method for a previously unsuccessful sympathectomy or recurrent palmar hyperhidrosis if the surgeon acknowledges possible anatomic variations. Lin (2001) reoperated 42 patients using the technique of video-assisted thoracoscopic resympathectomy. One of the causes of recurrent palmar hyperhidrosis after primary transthoracic endoscopic sympathicotomy or sympathectomy (TES) was the existence of Kuntz fibers. Drott et al. (1993) and Fritsch and Mach (1975) encountered a Kuntz nerve in approximately 10% of patients during surgery. It is often seen shimmering through the pleura lateral to the main stem. According to those authors, overlooking this nerve may lead to incomplete denervation of the upper extremity, resulting in surgical failure and early recurrence.

Wittmoser (1985) has used surgical treatment for primary erythrodermia that included the excision of the rami anastomotici of Kuntz. and reported a study of the influence of severing of the Kuntz nerve by endoscopic thoracic sympathicotomy in cases of chronic non-infectious rhinitis. Rhinitis was cured in 44.4% of patients, and was improved in 36.8% of patients.

Surgeons who undertake upper limb sympathectomy should be familiar with additional sympathetic connections, which have long been implicated as a cause of an unsuccessful outcome to sympathectomy. Some studies tudies suggest that the palmar hyperhidrosis is common in Asian populations, although to date only one study on nerve of Kuntz is available from India (Jit and Mukerjee, 1960). The present study is probably the second of its kind. Accordingly to build up a sound anatomical knowledge of the nerve of Kuntz among the Indian population more extensive studies are necessary.

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