Thoracic origin of a sympathetic supply to the upper limb: the 'nerve of Kuntz' revisited

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ABSTRACT

An understanding of the origin of the sympathetic innervation of the upper limb is important in surgical sympathectomy procedures. An inconstant intrathoracic ramus which joined the 2nd intercostal nerve to the ventral ramus of the 1st thoracic nerve, proximal to the point where the latter gave a large branch to the brachial plexus, has become known as the 'nerve of Kuntz' (Kuntz, 1927). Subsequently a variety of sympathetic interneuronal connections down to the 5th intercostal space were reported and also described as the nerve of Kuntz. The aim of this study was to determine: (1) the incidence, location and course of the nerve of Kuntz; (2) the relationship of the nerve of Kuntz to the 2nd thoracic ganglion; (3) the variations of the nerve of Kuntz in the absence of a stellate ganglion; (4) to compare the original intrathoracic ramus with sympathetic variations at other intercostal levels; and (5) to devise an appropriate anatomical classification of the nerves of Kuntz.

Bilateral microdissection of the sympathetic chain and somatic nerves of the upper 5 intercostal spaces was undertaken in 32 fetuses (gestational age, 18 wk to full term) and 18 adult cadavers. The total sample size comprised 99 sides.

Sympathetic contributions to the first thoracic nerve were found in 60 of 99 sides (left 32, right 28). Of these, 46 were confined to the 1st intercostal space only. The nerve of Kuntz (the original intrathoracic ramus) of the 1st intercostal space had a demonstrable sympathetic connection in 34 cases, and an absence of macroscopic sympathetic connections in 12. In the remaining intercostal spaces, intrathoracic rami uniting intercostal nerves were not observed. Additional sympathetic contributions (exclusive of rami communicantes) were noted between ganglia, interganglionic segments and intercostal nerves as additional rami communicantes. The eponym nerve of Kuntz should be restricted to descriptions of the intrathoracic ramus of the 1st intercostal space. Any of these variant sympathetic pathways may be responsible for the recurrence of symptoms after sympathectomy surgery.

Key words: Nerve of Kuntz; intrathoracic ramus.

INTRODUCTION

Operations on the sympathetic nervous system have a long and colourful history (Drott, 1994). Originally, sympathectomies were undertaken for a group of disparate medical conditions: epileptic fits, glaucoma, exophthalmic goiter, facial neuralgia, migraine (Pick, 1970) and causalgia (Mokus et al. 1987). In current surgical practice the indications for performing sympathectomy are well defined. Palmar hyperhidrosis (Kux, 1978; Byrne et al. 1990; Edmonson et al. 1992; Hashmonai et al. 1992; Chen et al. 1994; Herbst et al. 1994; Sachor et al. 1994; Cohen et al. 1995; Kopelman et al.1996), complex regional pain syndrome (Singh et al. 1997) and on occasion, Raynaud's phenomenon (Milewski et al. 1985; Gordon et al. 1994) constitute the universally acceptable indications. In current surgical practice, the wide availability and application

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of thoracoscopic surgery offers a safer and technically easier surgical option; this has led to an increase in the number of sympathectomies being undertaken.

Important causes of an unsuccessful upper limb sympathectomy include sympathetic regeneration (Telford, 1935; Simmons & Sheehan, 1939; Smithwick, 1940; Felder et al. 1949; Baddeley, 1965; Haxton, 1971; Singh et al. 1998), residual sympathetic connections (Skoog, 1947; Alexander et al. 1949; Boyd, 1957) and alternate sympathetic pathways (Jit & Mukerjee, 1960). The increasing use of thoracoscopic sympathectomies has prompted a reappraisal of the sympathetic outflow to the upper limb and the causes of failures following surgery. The most widely cited of alternative sympathetic pathways is undoubtedly the nerve of Kuntz.

Albert Kuntz, a renowned neuroanatomist from the St Louis University School of Medicine, drew attention in 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 a large branch to the brachial plexus. Kuntz attributed instances of sympathetic recurrence to this neural variant because it afforded an alternative pathway to the brachial plexus following stellate ganglionectomy. This kindled an interest in defining other neural pathways, not only in relation to the 1st and 2nd thoracic nerves but, in addition, to the 3rd and 4th intercostal nerves as well. Thus Kirgis (1941), Kirgis & Kuntz (1942) and Jit & Mukerjee (1960), amongst others, demonstrated additional nerves of the upper 3 intercostal spaces—connections between somatic intercostal nerves and the sympathetic chain (Fig. 1). All subsequent variations noted were referred to by the same eponym, the nerve of Kuntz, even though these variations did not necessarily contribute to the brachial plexus. To date, none of these variants have been classified in terms of their anatomical or clinical relevance. This lack of clarity with respect to the spectrum of variations merits a reconsideration given the vast increase of sympathectomies undertaken at present. An appreciation of alternative pathways to the upper limb and its implications is therefore timely.

This study therefore aimed to evaluate the sympathetic and somatic nerves of the 2nd–5th intercostal spaces to determine: (1) the incidence, location and course of the nerve of Kuntz (in what follows, this eponym is restricted to the ramus joining the 2nd intercostal nerve to T1); (2) the relationship of the nerve of Kuntz to the 2nd thoracic ganglion; and (3) the variations of the nerve of Kuntz in the absence of a stellate ganglion. It also aimed (4) to compare the original intrathoracic ramus with sympathetic variations at other intercostal levels, and (5) to devise an appropriate anatomical classification of the nerves of Kuntz.

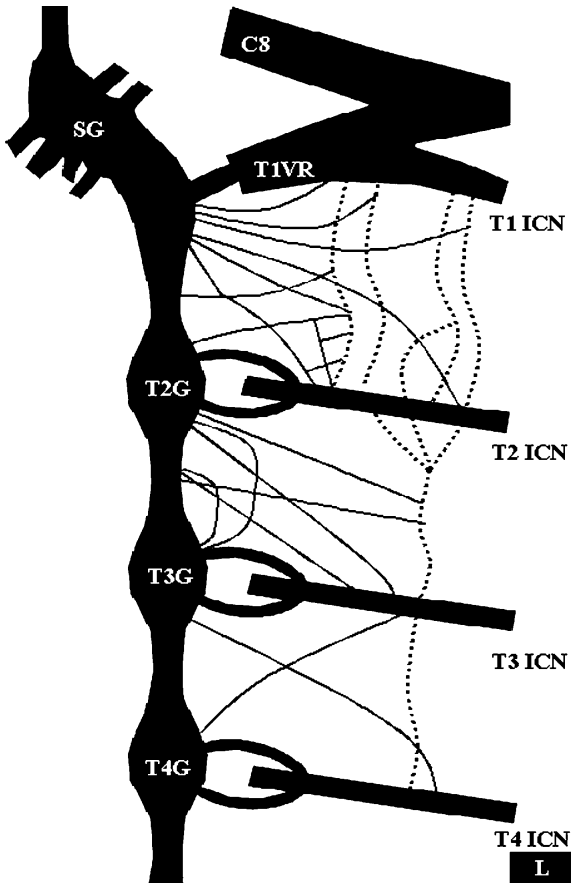

Fig. 1. Diagrammatic representation of spectrum of variations encountered in first 3 intercostal spaces. (Based on Jit & Mukerjee,1960, figs 1–5.) Macroscopic sympathetic connections between sympathetic chain and intercostal nerves are represented by (—) and inter-intercostal nerve connections by (···). Abbreviations for Figs 1–7: SG, stellate ganglion; ICG, inferior cervical ganglion; ICN, intercostal nerve; LCN, lateral cutaneous nerve; T1G, 2G, 3G, 4G, 5G, 6G, T1-6 ganglia; C7, 8, C7, 8 ventral rami; T1 VR, T1 ventral ramus; LT-BP, lower trunk of brachial plexus; T1, 2, 3, 4, 5, 6 ICN, T1–6 intercostal nerves; T1 LCN, T1 lateral cutaneous nerve; ITR, intrathoracic ramus.

MATERIALS AND METHODS

Extent of dissection

Bilateral microdissection of the sympathetic chain and somatic nerves of the upper 5 intercostal spaces was undertaken in 32 fetuses (gestational age, 18 wk-full term) and 18 adult cadavers. Dissection was undertaken in all but 1 side, an adult with dense pleural adhesions that precluded accurate dissection of the sympathetic chain and its connections. The total sample size comprised 99 sides.

The thoracic cavity and mediastinum were

eviscerated to expose the posterior thoracic wall. All neural connections between the sympathetic chain (from ganglia and interganglionic segments) and intercostal nerves were microdissected after gentle stripping of the parietal pleura. The arrangement of the nerve of Kuntz, and its proximity to the T2 ganglion, was documented. Statistical analysis using a binomial 2-proportion test was conducted.

RESULTS

Incidence, location and course of the nerves of Kuntz

Additional sympathetic connections and intrathoracic rami between the sympathetic chain and intercostal nerves of the upper 5 intercostal spaces were identified in 60 of 99 cases (left 32, right 28). No statistically significant difference between sides were noted ($z = 0.62$; $P = 0.54$). Of these variations, 46 were confined to the 1st intercostal space (Fig. 2). The nerve of Kuntz (the original intrathoracic ramus) of the 1st intercostal space was noted to have a demonstrable sympathetic connection in 34 cases (Fig. 2, types A, C; Figs 3, 5) and an absence of macroscopic sympathetic connections in 12 cases (Fig. 2, type B; Fig. 4). In those with a demonstrable sympathetic connection, an interesting communication was demonstrated in 7 cases between this intrathoracic ramus and the lateral cutaneous branch of the 1st intercostal nerve (Fig. 2, type C; Fig. 5). The intrathoracic ramus of the 1st

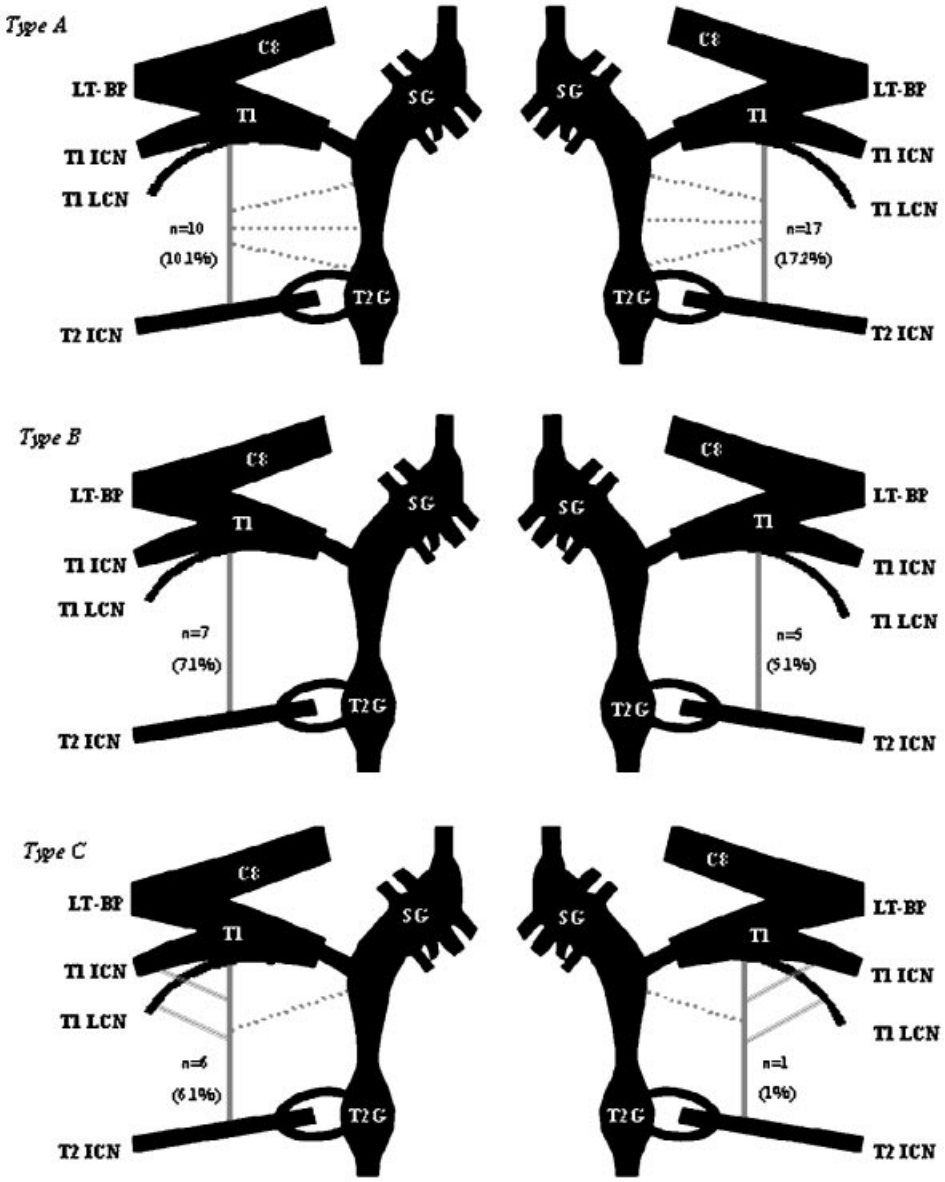

Fig. 2. Diagrammatic representation of the spectrum of intrathoracic rami encountered in the 1st intercostal space of 99 cadaveric dissections demonstrating types A–C. (For abbreviations, see caption to Fig. 1.) (Based on Jit & Mukerjee, 1960, figs 1–5.)

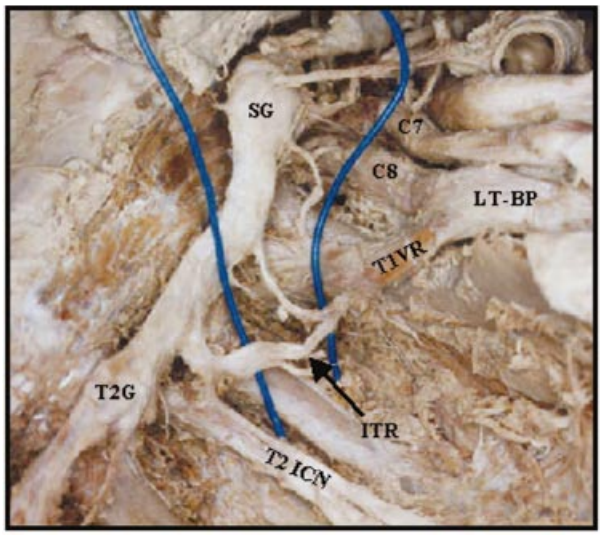

Fig. 3. Left superolateral view demonstrating intrathoracic ramus with macroscopic sympathetic communication (type A). (For abbreviations, see caption to Fig. 1.)

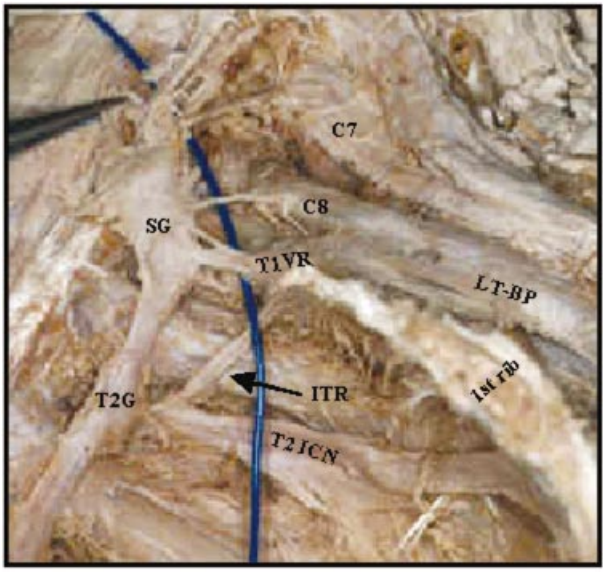

Fig. 4. Left superior oblique view demonstrating direct communication between T1 and 2 ventral rami (type B). There is no macroscopic sympathetic connection and the intrathoracic ramus ascends over the neck of the 2nd rib. (For abbreviations, see caption to Fig. 1.)

intercostal space was noted to join the 2nd intercostal nerve to either the ventral ramus of the 1st thoracic nerve (39 cases), the 1st intercostal nerve (2 cases) or the lateral cutaneous branch of the 1st intercostal nerve (5 cases).

The relationship of the nerve of Kuntz to the 2nd thoracic ganglion (*T2 ganglion*)

A T2 ganglion was found to be consistently present and located on the head of the 2nd rib at the

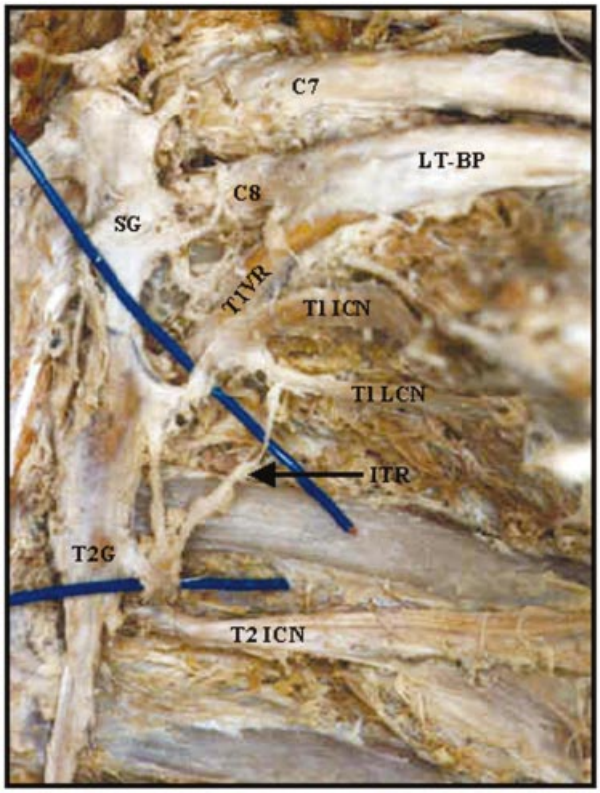

Fig. 5. Left superior oblique view illustrating communication between stellate ganglion and split intrathoracic ramus to lateral cutaneous nerve (type C). Note the macroscopic sympathetic connection. (For abbreviations, see caption to Fig. 1.)

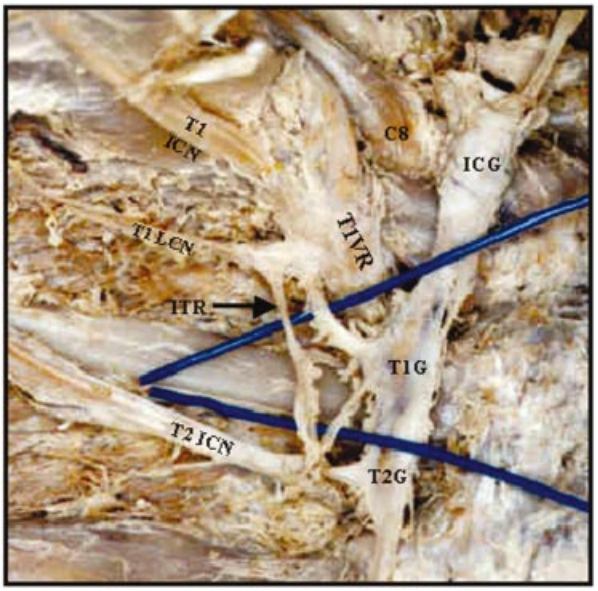

Fig. 6. Right superior oblique view illustrating intrathoracic ramus in the presence of an inferior cervical ganglion. (For abbreviations, see caption to Fig. 1.)

costovertebral junction. The intrathoracic ramus was located on the 2nd intercostal nerve 2.3–15.7 mm (adults) and 2.1–4.3 mm (fetuses) lateral to the T2

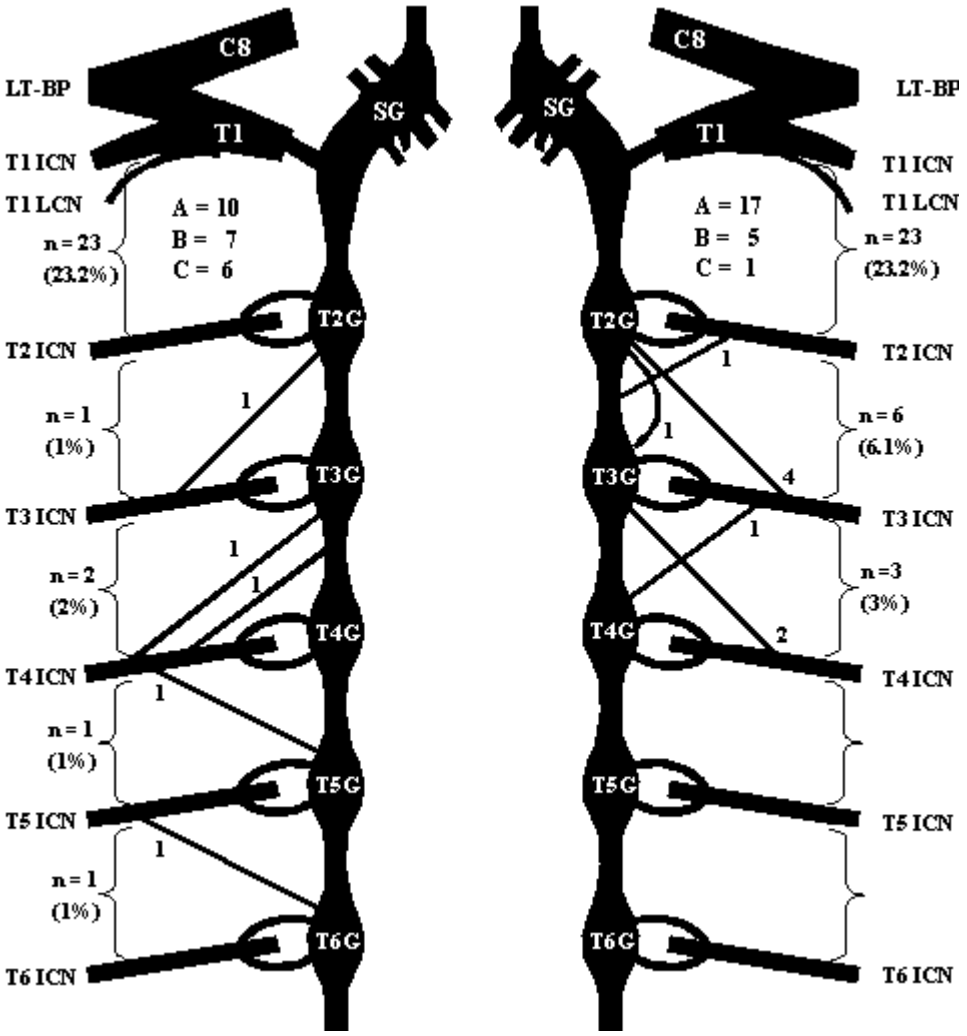

Fig. 7. Diagrammatic representation of additional sympathetic connections between 2nd and 5th intercostal spaces. (For abbreviations, see caption to Fig. 1.) (Based on Jit & Mukerjee, 1960, figs 1–5.)

ganglion. The 2nd thoracic ganglion was present in all specimens and no fusion was noted with either stellate, T1 or T3 ganglia.

The variations of the nerve of Kuntz in the absence of a stellate ganglion

The incidence of stellate ganglia was 90 % (45 of 50 cases) on the right, 94 % (46 of 49 cases) on the left side, giving a total incidence of 92 %. The incidence of inferior cervical ganglia was 10 % (5 of 50 cases) on the right, 6 % (3 of 49 cases) on the left, giving a total incidence of 8 %. A nerve of Kuntz together with distinct (i.e. not fused) inferior cervical and T1 ganglia was found in 3 of 99 cases (Fig. 6). Histological analysis (by haematoxylin & eosinophil staining) of the interganglionic segment between the aforementioned ganglia confirmed the absence of ganglionic cell bodies.

Comparison of the original intrathoracic ramus with sympathetic variations at other intercostal levels

Two rami communicantes were constantly noted either lateral, posterolateral or posteromedial to the 2nd–5th ventral rami, although not to the mixed spinal nerves. In intercostal spaces 2–5 an intrathoracic ramus connecting intercostal nerves was not observed. Additional sympathetic connections were observed to unite the intercostal nerves to ganglia (n = 10) and to the interganglionic segment (n = 3) of the sympathetic chain. An additional variation included an interganglionic loop between adjacent ganglia (n = 1) (Fig. 7).

DISCUSSION

Following Kuntz's initial report (1927) of the intrathoracic ramus between the 1st and 2nd thoracic ventral rami, anatomists have had a longstanding

interest in its variations. In addition to their anatomical significance, interest in these variations has been sustained because of their perceived role as an alternative sympathetic pathway in cases of recurrent sympathetic activity after a seemingly successful sympathectomy. A review of the literature reveals that the majority of the neural variations issuing from and adjacent to the sympathetic chain are located in the 1st intercostal space. The reported incidence of the nerve of Kuntz in the 1st intercostal space varies between 38 % (Jit & Mukerjee, 1960) and 75 % (Kirgis & Kuntz, 1942). Groen et al. (1987) reported an incidence of 66.7 %, while Lemmens & Drukker (1985) reported an incidence of 40 %. Our study found an incidence of 61 %.

An analogous intrathoracic ramus connecting the 2nd and 3rd intercostal nerves was described initially by Kirgis in 1941, and subsequently by Kirgis & Kuntz (1942), Kuntz (1946) and Jit & Mukerjee (1960). This was not observed in our series. This ramus, coursing over the 3rd rib, was postulated to conduct postganglionic sympathetic fibres from the 3rd ganglion to the 2nd intercostal nerve and from there via the 1st intrathoracic nerve to the brachial plexus. This somewhat tenuous pathway was proposed as a potential cause of a failed sympathectomy. The reported incidence of the intrathoracic ramus of the 2nd intercostal space varies widely, from 58 % (Kirgis, 1941) and 55 % (Kirgis & Kuntz, 1942), to 3 % (Jit & Mukerjee, 1960) and 0 % in this report.

In our series, additional sympathetic connections (14 %) (exclusive of rami communicantes) were noted between ganglia, interganglionic segments and intercostal nerves as additional rami communicantes in the 2nd–5th intercostal spaces (Fig. 7). Additional sympathetic connections in this region have not attained the same degree of anatomical and surgical significance as the additional sympathetic connections of the 1st intercostal space; this is not surprising, given the relative clinical insignificance of this component of the sympathetic nervous system.

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. The nerve of Kuntz attained importance previously during the era of stellate ganglionectomy. Its significance today, where a T2 ganglionectomy has become the preferred surgical option, merits reconsideration. Documentation of the sympathetic innervation to the upper limb is sparse. The incidence of stellate and inferior cervical ganglia in our study differs significantly from the weighted means derived from the literature: stellate ganglia: 92 % vs 71 % (Table 1); inferior cervical ganglia: 8 % vs 28 % (Table 2). Although previously unreported by Kuntz and his colleagues, we recorded the nerve of Kuntz in the presence of a distinct inferior cervical and T1 ganglia in 3 % of cases (Fig. 6).

Contrary to the anatomical literature, the surgical literature reports a 10 % incidence for the nerve of Kuntz (Drott, 1994; Gothberg et al. 1994). Appreciation of these variations will only follow a dissection of the pleura from the sympathetic chain. The surgical technique to effect sympathectomy currently varies from direct cautery of the sympathetic chain to a localised T2 ganglionectomy (without visualisation of the 2nd intercostal nerve). Our

Table 1. *Incidence of stellate ganglia*

Reference	Sample size	Stellate ganglion (%)*
Harman (1900)	12	9 (75)
Perlow & Vehe (1935)	48	40 (83)
Pick & Sheehan (1946)	25	20 (80)
Jamieson et al. (1952)	100	82 (82)
Mitchell (1953)	Not recorded	–(75–80)
Toni & Frignani (1955*a*)	40	24 (60)
Becker & Grunt (1957)	114	43 (38)
Hoffman (1957)	19	19 (100)
Jit & Mukerjee (1960)	100	80 (80)
Ellison & Williams (1969)	24	21 (88)
Groen et al. (1987)	6	6 (100)
Ramsaroop et al. (2001)	99	91 (92)
Range		38–100 %
Median		81 %
Weighted mean		71 %

* Note that the stellate ganglion is defined as a fusion of the inferior cervical and T1 ganglia.

Table 2. *Incidence of inferior cervical ganglia*

Reference	Sample size	Inferior cervical ganglion (%)
Harman (1900)	12	3 (25)
Potts (1925)	1 case report	–
Perlow & Vehe (1935)	48	8 (17)
Pick & Sheehan (1946)	25	5 (20)
Jamieson et al. (1952)	100	18 (18)
Mitchell (1953)	Not recorded	–(20–25)
Toni & Frignani (1955*a*)	40	3 (8)
Becker & Grunt (1957)	114	71 (62)
Jit & Mukerjee (1960)	100	20 (20)
Ellison & Williams (1969)	24	3 (13)
Ramsaroop et al. (2001)	99	8 (8)
Range		8–62 %
Median		19 %
Weighted mean		28 %

$\frac{^{**}\Sigma(nx)}{\Sigma(n)}$

documentation suggests that the nerve of Kuntz is located between 2.3–15.7 mm lateral to the T2 ganglion in adults. Given the operative magnification afforded by the currently used thoracoscopic equipment, it is possible that the nerve of Kuntz variations lie outside the field of surgical endeavour. It is also possible that there may be an inadvertent resection or avulsion of these neural pathways during surgery leading to its underappreciation.

Notwithstanding the spectrum of variations in this location, there has been no attempt to categorise these. The distribution of the sympathetic neural pathways in the 1st intercostal space has enormous clinical significance given the current surgical preference to perform an isolated T2 ganglionectomy to effect upper limb sympathectomy. The intrathoracic ramus is most prevalent in the 1st intercostal space. Given the spectrum of variations encountered, a classification of the 'nerves of Kuntz' of the 1st intercostal space is proposed.

Proposed classification of the intrathoracic ramus (between the 2nd intercostal nerve and ventral ramus of the 1st thoracic nerve) of the 1st intercostal space (Fig. 2)

Type A. A demonstrable sympathetic connection to either the stellate, T2 ganglia or interganglionic portion of sympathetic chain (this was noted in 27%; Fig. 3).

Type B. No macroscopic sympathetic connections are evident (this arrangement was noted in 12.1%; Fig. 4).

Type C. Macroscopic sympathetic connections to either the T1 intercostal nerve or its lateral cutaneous nerve. These sympathetic connections may have clinical significance in those patients with axillary hyperhidrosis because the lateral cutaneous nerve supplies the axilla (Williams et al. 1995) (this type was noted in 7%; Fig. 5).

An appreciation of the lower (distal to the 1st intercostal space) additional sympathetic connections may assume significance given the resurgence of surgical procedures on the lower sympathetic chain e.g. thoracoscopic splanchnicectomy undertaken for chronic upper abdominal pain.

The eponym, nerve of Kuntz, should be restricted to descriptions of the intrathoracic ramus of the 1st intercostal space only. Variations between the sympathetic chain and somatic nerves at other intercostal levels should be referred to as 'additional sympathetic connections' or 'additional rami communicantes.'

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