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Chapter 2.2

Surgical Anatomy of the 10th and 11th Intercostal, and Subcostal Nerves: Prevention of Damage During Lumbotomy.

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ABSTRACT

Background: In a descriptive, inventorial anatomical study we mapped the course of the 10th and 11th intercostal nerves, and the subcostal nerve in the abdominal wall to determine a safe zone for lumbotomy.

Methods: We dissected 11 embalmed cadavers, of which 10 were analyzed. The 10th and 11th intercostal nerves, and the subcostal nerve were dissected from the intercostal space to the rectus sheath. Analysis was done using computer assisted surgical anatomy mapping. A safe zone and an incision line with a minimum of nerve crossings were determined

Results: The 10th and 11th intercostal nerves were invariably positioned subcostally. The subcostal nerve lay subcostally but caudal to the rib in 4 specimens. The main branches were located between the internal oblique and transverse abdominal muscles. The nerves branched and extensively varied in the abdominal wall. A straight line extended from the superior surface of the 11th and 12th ribs indicated a zone with lower nerve density. In 5 specimens the 10th and 11th intercostal nerves crossed this line from the superior surface of the 11th rib. In 5 specimens neither the 11th intercostal nerve nor the subcostal nerve crossed this extended line from the superior surface of the 12th rib up to 15 cm from the tip of the rib

Conclusions: Damage is inevitable to branches of the 10th or 11th intercostal nerve, or the subcostal nerve during lumbotomy. However, an incision extending from the superior surface of the 11th or 12th rib is less prone to damage these nerves. Closing the abdominal wall in 3 layers with the transverse abdominal muscle separately might prevent damage to neighboring nerves

INTRODUCTION

Flank bulge is a common complication after lumbotomy for renal surgery. The cause of this complication is often iatrogenic damage to the nerves supplying the abdominal wall musculature due to the initial incision or to closing sutures after the procedure. This denervation results in laxity and bulging of parts of the abdominal wall.[1-3] It is a clinically innocuous complication but also inconvenient and it can be esthetically disturbing for patients.[4]

The incidence of flank bulge after renal surgery has been reported with a large variability. In 1974 a 3% incidence of bulging was found after nephrectomy using a classic flank incision.[5] This was in accordance with a 3.6% incidence using a miniflank incision.[6] However, a 49% incidence of flank bulge after nephrectomy was reported in a telephone survey with patients who reported flank bulge.[4]

It is unclear how lumbotomy can be performed without nerve injury. The intercostal nerves are classically described to run in the subcostal groove.[7, 8] Others found that they run mid intercostally[1, 9] or more caudal in the intercostal space.[10] The lower intercostal nerves divide and give off 1) an anterior branch innervating the skin and the external oblique muscle, and 2) a posterior branch innervating the internal oblique and transverse abdominal muscles.[1, 8] The main trunk of the intercostal nerves runs a course between the internal oblique and transverse abdominal muscles.[11] The 9th to 12th intercostal nerves conjoin to form a plexus.[8, 12]

We mapped the course of n10, n11 and n12 in the lumbotomy area using the new analytical method, CASAM, and defined a safe zone for the lumbotomy incision.

METHODS

Materials

In this descriptive inventorial anatomical study 11 embalmed specimens, including 4 male and 7 female cadavers with intact flanks, were dissected unilaterally. All landmarks were assessed in situ at dissection and standardized photographs were taken (Figure 1). One male body was excluded from study due to dissimilar anatomy, ie poor pelvic alignment. In this case the analytical method caused distortion of the body contour and the nerves could not be analyzed properly.

The epidermis was removed from just below the iliac crest up to the 10th rib from the posterior intercostal space to the lateral edge of the rectus abdominis muscle. The neurovascular bundles of n10, n11 and n12 were identified below the ribs and followed through the abdominal wall to the rectus abdominis muscle. Surrounding tissue was removed while preserving the underlying tissue. Neurovascular bundle nerves were marked with yellow pins.

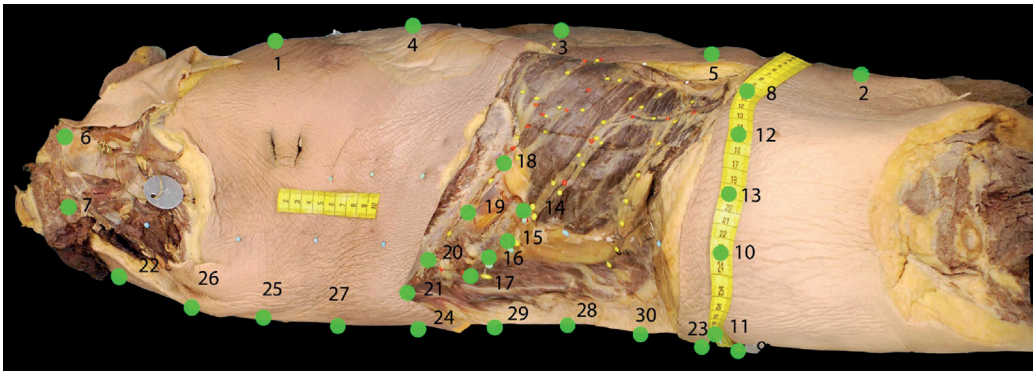

Figure 1.Landmarks (1 to 30, green circles) used for analysis

Measurements

General measurements were made in the specimens. The distance between the anterior superior and posterior superior iliac spines was measured to indicate the width of the body. The distance between the sternal angle (Louis' angle as landmark 1) and the pubic symphysis (landmark 2) were measured to assess the length of the body (Figure 1). The distance from n10, n11 and n12 to the caudal surface of the rib was measured. The number of branches of each nerve was counted. Nerve diameter was measured below the rib and in the abdominal wall. Branches with a diameter of less than 1 mm were considered small. An incision line with a minimum of crossing nerves was determined. The distance of the first branch passing this line was measured from the tip of the 11th or 12th rib.

Computer-Assisted Surgical Anatomy Mapping (CASAM)

All photos were taken according to a standardized protocol, which is a required condition to enter photos into CASAM. The cadaver was placed on a screen, which was marked with a cross to facilitate standardized positioning. The cadaver was placed on the contralateral flank, supported subcostally and fixed in a 90-degree position with 2 U-shaped constructions that were especially made for this study. To prevent rotation of the thorax and pelvis the back and pelvis were supported in

the U-shaped construction. Landmarks were marked with pins after positioning the specimens. A tape measure was pinned between the anterior superior and the posterior superior iliac spine to ensure that the landmarks between were on the same line.

All photographs were taken using a Nikon® D60 camera with a 50 mm 1:2.8 DGmacro lens (Sigma, Tokyo, Japan). The camera was set in a tripod and fixed in a position perpendicular to the specimen at 160 cm from the specimen. The camera flash was disabled and a self-timer was used to avoid any camera movement. The camera was centered on the middle of the line between the posterior tip of the acromion, and the middle of the anterior superior and posterior superior iliac spine.

CASAM was used to compare the photographs of the different cadavers and make clinically relevant information visible. Photographs of the left flank were mirrored to create the same view and make the right and left sides comparable.

To perform step 1 (morphing) Magic Morph was used. In this process the shape and size of each cadaver was defined using predetermined landmarks. This was followed by calculating and computing an average body shape and size. Thin plate spline transformation was used as a morphing algorithm.[13, 14] All bodies were shaped to exactly match the shape and size of the computed and calculated average body. Photoshop® CS4 was used to compile all data and visualize the relevant anatomy.

A safe zone was determined by coloring the nerve-free zones, excluding the ribs. Safe zones were compiled into 1 image and a gradient of free zones was visualized. These gradients were colored and a percent was assigned to each area.

RESULTS

Topographic Anatomy

The median distance between the anterior superior and the posterior superior iliac spine was 24 cm (range 19.8 to 30). The median distance from the pubic symphysis to the sternal angle was 48.5 cm (range 40 to 50). We found that n10 and n11 ran subcostally and were flush to the caudal surface of the rib in all specimens. In 6 specimens n12 was positioned subcostally. The subcostal nerve was found 1, 1.5, 2 and 3 cm caudal to the 12th rib in 4 specimens. In 8 of 10 specimens (80%) n10 and n12 branched. The 11th intercostal nerves branched in 9 specimens (90%). When n10, n11 or n12 branched, there were 2 to 4 branches. In 1 specimen (10%) n10 and n11 crossed, and in 3 (30%) n11 and n12 crossed.

In the anterior abdominal wall n10 and n11 ran together in 2 specimens (20%). In 4 specimens (40%) n11 and the subcostal nerve ran together in the abdominal wall. Average nerve diameter was 2.2 mm caudal to the rib and 2.1 mm in the abdominal wall.

Computer-Assisted Surgical Anatomy Mapping (CASAM)

All landmarks except the superior surface of the first thoracic vertebra were visible in all photographs. Since this landmark was not visible in the photographs of 3 specimens (30%), it was not used for computer analysis. However, landmarks between the superior surface of the first thoracic vertebra and the superior surface of the sacral bone were used. The tip of the 12th rib was not visible in the photos of 2 specimens (20%) because the rib was too small and the abdominal wall obstructed the view. Figure 2,A shows the course of 10 intercostal and subcostal

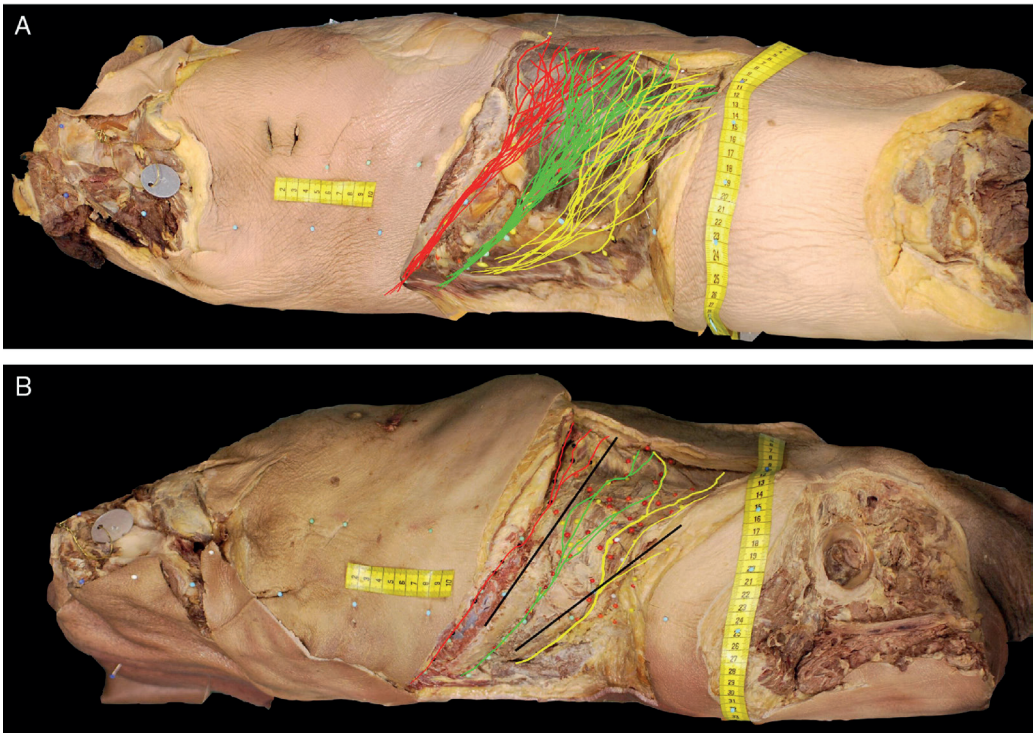

Figure 2. One standardized specimen created from 10 specimens shows n10 (red lines), n11 and n12.
A, abdominal wall. Yellow lines indicate n11. Green lines indicate subcostal nerve.
B, projection of extrapolated lines (black lines) from rib superior surface. Green lines indicate n11. Yellow lines indicate n12.

nerves visualized in 1 average body. Little variation was noted in the course of n10 and n11 in the intercostal space. The position of the 12th rib varied among specimens, resulting in variation of the position of n12 to the caudal surface of the 11th and 12th ribs. The nerves first branched in the abdominal wall and after this large variation existed in terminal branches. Figure 3,A shows safe zones in the abdominal wall with the percents assigned to these zones. A safe zone was found in the intercostal space between the 10th and 11th ribs, and below the 11th rib. The 11th and 12th ribs were part of this safe zone (Figure 3, B).

The safe zone, that is the zone with a low chance of nerve injury, for lumbotomy appeared to project in a straight line extrapolated from the superior surface of the 11th and 12th ribs. No absolute safe zone was identified. In our specimens we investigated how often the intercostal or subcostal nerve crossed this imaginary line.

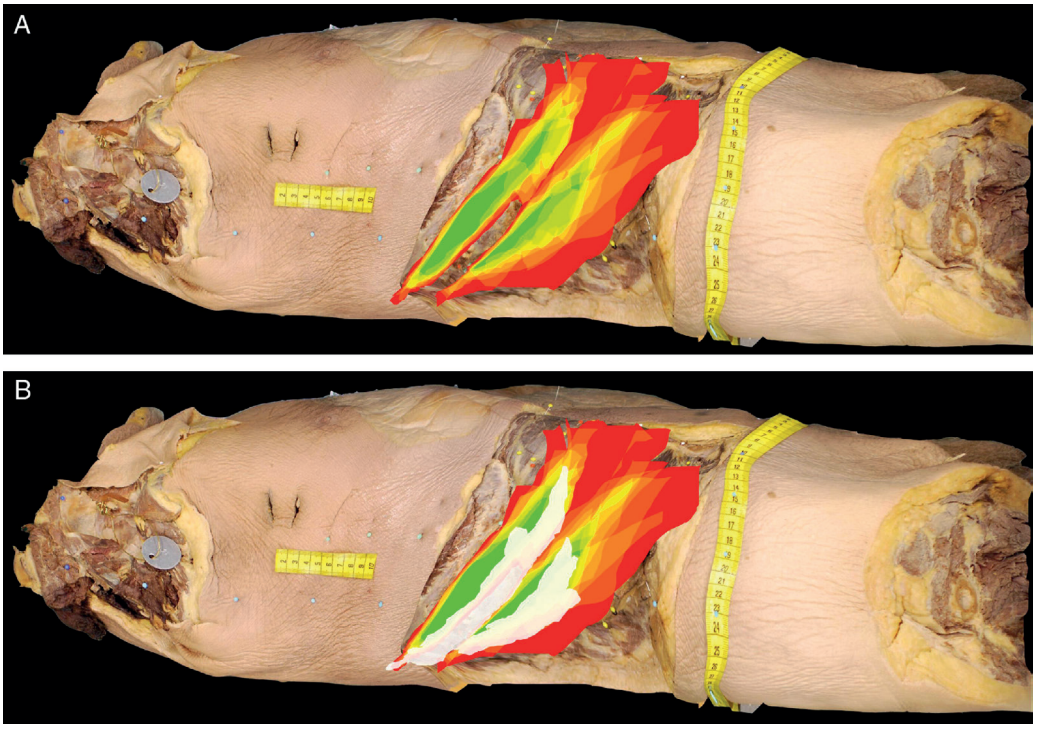

Figure 3. Safe zones in abdominal wall between n10 and n11, and n11 and n12.

A, 100% safety where no nerves run in certain parts of body (green areas).
B, additional white area represents position of 11th and 12th ribs, which partly overlaps safe zone. Red areas indicate 10% safety. Orange gradient from red to yellow represents 20% to 50% safety. Yellow areas indicate 60% safety. Yellow to green gradient represents 70% to 90% safety.

In 6 specimens (60%) neither n10 nor n11 crossed an extrapolated line from the superior surface of the 11th rib (Figure 2, B). When n10 or n11 crossed this line, the distance from the tip of the 11th rib to the first passing branch was 0.5 to 7 cm (Table 1). In 5 specimens (50%) n11 and n12 did not cross an extrapolated line from the superior surface of the 12th rib in the lumbotomy area, 15 cm from the tip of the rib. Only small branches crossed this line in 1 specimen (10%). The distance of the nerves crossing this line was 5 to 13.5 cm.

NR.	11th-n10 or n11*	12th-n11 or n12*
1	-	9.5*
2	-	6.7*
3	-	-
4	-	19.5
5	-	11.5*
6	4	4.5+
8	0.5	-
9	4.5	-
10	7	15
11	-	5*

Table 1. Distance from rib tip to first nerve branch crossing extrapolated line from superior surface of ribs
* Considered within lumbotomy area
+ Only small branches crossed line and no branch crossed extrapolated line from rib.

DISCUSSION

Flank bulge is a common, disturbing complication after lumbotomy.[4-6] It is caused by damage to intercostal and subcostal nerves supplying the abdominal wall musculature, resulting in paralysis and atrophy of these muscles.[1-3] It is not yet clear how nerve injury can be minimized during lumbotomy. Therefore, we mapped the course of n10, n11 and n12 in relation to relevant anatomical structures to define a safe zone for lumbotomy.

A new method of analysis was used to visualize structures of clinical interest in the abdominal wall. The essence of this method is an especially made computer program that uses body landmarks to calculate an average body. CASAM revealed that damage may be minimized using an incision extending from the superior

surface of the 11th or 12th rib. In 60% of specimens no or minimal damage to the intercostal and subcostal nerves would be expected if incision length was limited to 15 cm from the tip of the rib. Diblasio et al previously proposed an incision over the superior surface of the 11th rib, starting 5 cm ventral and ending 3 cm dorsal to the tip of the rib, to limit damage to the intercostal nerves.[6] This is in agreement with our findings (Figure. 2, A). If an incision is made over the superior surface of the ribs, damage to the intercostal nerves will be minimal.

An accurate safe zone cannot be defined with 100% certainty based on data on 10 specimens. Due to extensive variation in the course of the terminal nerve branches in the abdominal wall a 100% safe zone could not be defined. This means that damage to branches of the intercostal nerves during lumbotomy cannot be prevented in all cases.

However, certain aspects of positioning the anatomical specimens may have hampered analysis. The cadavers could not be placed in the flank position with lateral flexion of the lumbar region, which is common practice for lumbotomy. It might be possible in vitro that in this position the intercostal space and the space between the nerves in the abdominal wall are smaller than in a patient who undergoes lumbotomy. Furthermore, the tissue of embalmed cadavers is less voluminous than in a living individual since slight contraction occurs during the embalming procedure. Damaging cutaneous branches does not result in paralysis of the abdominal wall musculature and, thus, does not result in flank bulge. All of this might contribute to an underestimation of the safe zone in the intercostal space and abdominal wall.

It is unclear whether damage to the intercostal and subcostal nerves is caused by the initial incision alone. Nerve damage might also be caused by forces induced by the retractor. Peripheral nerves are prone to damage due to traction. In addition, nerve injury might be caused by closing the incision and, thus, by entrapment.[15] The intercostal nerves ran a course between the internal oblique and the transverse abdominal muscles in all specimens (the neurovascular plane). Closing the incision in 3 muscle layers separately, ie the transverse abdominal muscle separately, could decrease the risk of nerve entrapment.

Damage to nerves in the abdominal wall may not necessarily result in flank bulge. The intercostal nerves crossed, branched and ran together in the abdominal wall in some specimens, resulting in overlap of the areas innervated by individual nerves. Minimizing damage to intercostal nerve branches might prevent flank bulge. Further research must be done to evaluate this hypothesis.

Conclusion

Damage to branches of n10, n11 and n12 during lumbotomy can be minimized. Incisions extending from the superior surface of the 11th or 12th rib seem to be less prone to cause damage to the intercostal and subcostal nerves. Closing the abdominal wall in 3 layers with the transverse abdominal muscle separately might prevent damage to neighboring nerves.

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