Surgical placement of rectus sheath catheters in a cadaveric cystectomy model

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ABSTRACT

INTRODUCTION Surgically inserted rectus sheath catheters (RSCs) are used increasingly for analgesia after cystectomy and other abdominal surgery. Currently, there is little information on the optimal positioning of RSCs to allow maximal spread of local anaesthetic. This study sought to assess the spread of dye injected via RSCs and to highlight the extent of its coverage in a fresh unembalmed cadaveric cystectomy model in order to confirm the nerve endings that are likely to be anaesthetised with RSCs.

METHODS Four cadavers underwent lower midline incision with limited bladder mobilisation. A RSC was inserted into the eight hemiabdomens. The RSCs were positioned either anterior ($n=5$) or posterior to the rectus muscle ($n=3$). Dye was injected down the RSCs to evaluate spread. The eight hemiabdomens were dissected anatomically to determine the surface area of dye spread and nerve root involvement.

RESULTS The mean surface area of dye spread with anteriorly placed RSCs was 30.6cm² anterior and 25.9cm² posterior to the rectus muscle. The mean surface area of dye spread with posteriorly placed RSCs was 11.3cm² anterior and 37.3cm² posterior to the rectus muscle. The mean number of nerve roots stained with anteriorly and posteriorly placed RSCs was 3.8 and 2.7 respectively. Subcutaneous spread of dye was seen with one anterior RSC insertion. Peritoneal spread was seen with one anteriorly positioned RSC.

CONCLUSIONS This study has demonstrated efficient nerve root infiltration with anteriorly and posteriorly positioned RSCs. It appears that dye spreads between the fibres of the rectus muscle rather than out laterally to the nerve roots when spreading from its initial compartment.

KEYWORDS

Rectus sheath catheter – Surgically inserted – Cadaver model

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Currently, there is continued need for open abdominal surgery including radical cystectomy (RC), which routinely requires a lower midline incision (LMI). Infusion of local anaesthetic down rectus sheath catheters (RSCs) is one technique that is used after RC to provide postoperative analgesia with good effect.^{1,2} The use of RSCs for postoperative analgesia has been reported to reduce postoperative length of stay by up to 50%.^{2,3}

However, the optimal positioning of RSCs has not been described. There is a relative paucity of published methods for surgically inserted RSCs, three of which describe RSC insertion above the arcuate line, anterior to the posterior rectus sheath,^{4–6} with a further study describing catheter insertion at the level of the musculofascial closure.⁷ An accurate understanding of the mechanism of action of RSCs is important given that LMIs generally extend below the arcuate line, at which there is no posterior rectus sheath, which may therefore potentially limit the efficacy of this technique. Consequently, the aim of this study was to accurately map the extent of spread of a dye injected down RSCs when they

were positioned either from anterior to the rectus muscle but posterior to the anterior rectus sheath or from posterior to the rectus muscle in front of the transversalis fascia.

Methods

Approval for the study was obtained from the University of British Columbia (UBC) Clinical Research Ethics Board. Four fresh frozen cadavers (1 male, 3 female) with virgin abdomens were obtained with permission from the Department of Cellular and Physiological Sciences at UBC. The cadavers were donated to the Faculty of Medicine and there was appropriate consent for use in research.

The four cadavers underwent LMI from two finger breadths below the umbilicus to the pubis, as is our standard practice for RC *in vivo*. The LMI was then developed down to the extraperitoneal space. The cadavers underwent limited bladder mobilisation with development of the extraperitoneal space, and identification and mobilisation of the gonadal vessels and vas deferens in the male cadaver, as a

form of sham RC. Care was taken to avoid disruption of the peritoneum owing to the risk of contamination and soiling from peritoneal contents. Once this was complete, the eight hemiabdomens underwent RSC insertion. RSCs were positioned either anterior ($n=5$) or posterior to the rectus muscle ($n=3$).

Using blunt dissection, a plane was developed between the rectus muscle and the anterior sheath (for anteriorly positioned RSCs) or the transversalis fascia inferiorly (for posteriorly positioned RSCs). A 17G needle was then passed 3cm away from the superior extent of the incision into the dissected space. Once the needle was in position, an epidural catheter was threaded down so that the tip of the catheter came to lie at the furthest extent of the wound within the predissected plane.

After all eight RSCs were positioned correctly, they were sutured in place and the LMI was closed using a standard mass closure technique, taking care to approximate the edges of the dissected space into the closure. The skin was closed with clips. The wound incision length and distance from catheter tip to skin were recorded. Green acrylic dye (Craft Smart®; Michaels, Irvine, TX, US) in normal saline was injected down each RSC followed by layer-by-layer dissection by a blinded anatomist (CK) to determine the extent of dye spread.

The surface area of spread of dye was recorded for the subcutaneous fat plane, the plane anterior to the rectus muscle and the plane posterior to the rectus muscle. A note was made of any peritoneal spread of dye and whether there was evidence of dye spread between the rectus muscle fibres. The nerve roots were identified and likely dermatomal distribution of the dye was also recorded.

Results

Three of the fresh frozen cadavers were female with the other one male. The mean age at death was 82 years and they had a mean body mass index of 22kg/m². The positioning of the RSC along with dye volume is outlined in Table 1. *In vivo*, it is our routine practice to 'prime' RSCs

with 20ml of local anaesthetic solution and an attempt was therefore made to recapitulate this in this model. For cadaver 1, this was not possible owing to resistance on injection, which may account for the relatively lower surface area of spread observed. The median incision length was 115mm (range: 110–115mm) with a median catheter tip-to-skin distance of 145mm (range: 110–165mm). Figure 1 demonstrates the positioning of the RSCs in the anterior abdominal wall.

Table 2 outlines the spread of dye in the eight hemiabdomens and Figure 2 shows examples of findings in the cadaveric specimens after injection. In four of the five anteriorly positioned RSCs there was migration of dye into the posterior plane with evidence of intrarectal spread in three of the five cases. One hemiabdomen was found to have peritoneal spread in an anteriorly placed RSC owing to very poor rectus tissue and decomposition. There was no evidence of peritoneal puncture.

The total surface area covered by dye, per cadaver, across all planes varied from 2cm² to 135cm² (median: 48.5cm²). The number of dermatomal nerve roots stained with the dye varied from 1 to 5 with a median of 4 nerve roots involved. The dermatomal nerve roots affected ranged from T9 to L1.

Discussion

This study demonstrates the importance of correct RSC positioning in relation to the spread of local anaesthetic solution after sham RC with a LMI and provides the surgeon with new information on the optimal placement of RSCs. To date, there has been no published evaluation of the potential mechanisms of action of RSCs. While it could be assumed that filling the rectus space with local anaesthetic would be enough to provide analgesia, the results of this cadaveric study suggest other mechanisms may be at play. *In vivo*, RSCs that are placed surgically provide successful analgesia, even if placed anterior to the rectus muscle. It is likely that simple diffusion and absorption of local anaesthetic within the rectus space is too simplistic a view of the mechanism of action.

Table 1 Rectus sheath catheter (RSC) insertion, dye volume, incision length, RSC depth and level of arcuate line as estimated by dermatomal level

Specimen number	Side	Plane	Dye volume	Incision length	Catheter tip-to-skin distance	Level of arcuate line
1a	Left	Posterior	12ml	115mm	150mm	T11
1b	Right	Posterior	8ml	115mm	165mm	T11
2a	Left	Anterior	20ml	115mm	130mm	T10
2b	Right	Anterior	20ml	115mm	120mm	T10
3a	Left	Anterior	17ml	110mm	110mm	T11
3b	Right	Anterior	20ml	110mm	140mm	T11
4a	Left	Posterior	20ml	115mm	155mm	T11
4b	Right	Anterior	20ml	115mm	155mm	T11

Figure 1 Photographs of cadaver specimens showing positioning of the rectus sheath catheters (RSCs) with nerve root involvement and final appearance of catheters. **A:** Anterior rectus sheath uncut with bilateral RSCs entering inferiorly. **B:** Dissected left anterior rectus sheath demonstrating identification of nerve roots T11–L1 with dye from a posteriorly inserted RSC appearing at the lateral margin of the rectus muscle. **C:** RSC inserted posteriorly using dissection-under-vision technique. Nerve roots T12 and L1 demonstrated. **D:** Dissected left anterior rectus sheath demonstrating position of anteriorly placed RSC after dye injection. **E:** Bilateral RSCs inserted from superior to inferior demonstrating their final position following closure.

Our study has shown that anteriorly placed RSCs allow dye to migrate to the space posterior to the rectus muscle. Furthermore, there was evidence of dye between the muscle

fibres in three of the five anteriorly placed RSCs. This suggests that dye spreads between the muscle fibres when injected down RSCs to fill the posterior rectus space, thereby communicating with the nerve roots of the anterior abdominal wall.

In one of the anteriorly placed RSCs where no intrarectal dye was seen, the cadaver had undergone previous radiotherapy, which had resulted in scarring of the rectus muscle (specimen 4b). Despite this, a large surface area of the posterior space was covered by dye. In this case, it is likely that the dye spread out laterally in the anterior plane before migrating underneath the rectus muscle to fill the posterior plane. The same could be true for specimen 3a.

In posteriorly placed RSCs, it is likely that dye injection fills the posterior space first, before migrating anteriorly between the fibres of the rectus muscle. This is evidenced by the results described above. It therefore seems probable that *in vivo*, anteriorly placed RSCs allow the spread of local anaesthetic mainly between the fibres of the rectus muscle rather than spreading laterally and underneath the rectus muscle. This mechanism is likely to take effect in addition to diffusion of local anaesthetic down its concentration gradient and absorption of local anaesthetic into local tissue.

Understanding the anatomy of the anterior abdominal wall is essential to establishing the mechanism of action of RSCs. The rectus abdominis muscle runs from the xiphisternum and costal cartilage superiorly to the pubic crest inferiorly.⁸ From posterior to anterior, the transversus abdominis, internal oblique and external oblique make up the other muscles of the anterior abdominal wall. These muscles have their ‘bellies’ positioned laterally with their thick fibrous aponeuroses fusing medially.⁹ It should be noted that the arcuate line marks an anatomic transition point below which all of the aponeurotic layers of the rectus sheath (except the transversalis fascia) pass together in front of the rectus abdominis muscle.¹⁰

Three tendinous intersections interrupt the rectus abdominis muscle and the overlying fibrous sheath anteriorly; these are at the level of the xiphisternum, the umbilicus and halfway between the two.⁸ These intersections do not

Table 2 Surface area of spread of dye, dermatomal spread, nerve roots covered and evidence of peritoneal spread

Specimen number	Plane	Anterior to rectus muscle plane	Intrarectal spread	Posterior to rectus muscle plane	Total surface area covered	Dermatomal spread	Number of nerve roots covered	Peritoneal spread
1a	Posterior	0cm ²	Yes	50.0cm ²	50.0cm ²	T11 / T12 / L1	3	No
1b	Posterior	0cm ²	No	2.0cm ²	2.0cm ²	L1	1	No
2a	Anterior	75.0cm ²	Yes	60.0cm ²	135.0cm ²	T10 / T11 / T12 / L1	4	No
2b	Anterior	58.5cm ²	Yes	1.5cm ²	66.8cm ²	T9 / T10 / T11 / T12 / L1	5	No
3a	Anterior	0cm ²	Yes	33.0cm ²	33.0cm ²	T10 / T11 / T12 / L1	4	No
3b	Anterior	7.5cm ²	No	0cm ²	7.5cm ²	T11 / T12	2	Yes
4a	Posterior	33.8cm ²	Yes	60.0cm ²	93.8cm ²	T10 / T11 / T12 / L1	4	No
4b	Anterior	12.0cm ²	No	35.0cm ²	47.0cm ²	T10 / T11 / T12 / L1	4	No

Figure 2 Photographs of cadaver specimens following injection. **A:** Posterior dye spread and rectus muscle involvement (specimen 1a). **B:** Bilateral anteriorly inserted rectus sheath catheters (RSCs) with spread in the anterior plane (specimens 2a and 2b). The anterior rectus sheath has been reflected laterally to reveal the rectus muscles bilaterally. **C:** Dye spread from an anteriorly positioned RSC (dissected out) in the posterior plane (specimen 3a). **D:** Dye spread from an anteriorly positioned RSC (removed) in the posterior plane (specimen 4b). Note the arcuate line and dye spread over the transversalis fascia.

extend through the full thickness of the rectus abdominis muscle, which therefore creates a potential space that runs from xiphisternum to pubis (with free communication along its length) posterior to the rectus abdominis muscles, anterior to the posterior rectus sheath above the arcuate line and anterior to the transversalis fascia below the arcuate line.^{8,11} It is this space that contains the nervous supply of the rectus muscle and anterior abdominal wall.²

After exiting the vertebral column, these nerve roots divide into anterior and posterior rami, with the anterior divisions innervating the anterior abdominal wall.¹¹ From their origin in the spinal cord, the nerves continue anteriorly from the intercostal space, passing between the internal oblique and the transversus abdominis (in what is known as the transversus abdominis plane), and communicate via the rectus sheath plexus that runs alongside the deep inferior epigastric artery.¹² Anatomically, it is clear that the RSC will bathe the rectus sheath plexus in local anaesthetic, resulting in analgesia from block of these sensory nerves.

Optimal surgical technique of rectus sheath catheter insertion

This cadaver study demonstrates that both anterior and posterior placement of RSCs is feasible and results in adequate nerve root involvement, at least in this model. Ideally, in keeping with the anatomical course of the nerves supplying sensory innervation to the anterior abdominal wall, RSCs should be placed in the posterior plane. This is important

because there was no evidence of peritoneal spread with posteriorly positioned RSCs. On the other hand, if this is not practicable, then anterior placement is likely to work equally well, given the results of this study and anecdotal evidence from our *in vivo* practice.

Our findings suggest that where possible, RSCs should be inserted using a tunnelling technique in the posterior plane that lies between the rectus muscle and the transversalis fascia when inserting them below the RSC. However, if this space is disrupted as a result of surgical dissection, then the anterior plane appears to effectively allow the distribution of dye on to the appropriate nerve roots.

Study limitations

While this is the first published study evaluating the mechanism of action of RSCs, there are some limitations that need to be considered. First, a cadaver study cannot replicate the *in vivo* circulation of a patient, which allows more diffusion and absorption of fluid within the anterior abdominal wall. This may account for some of the mechanism of action of RSCs. Second, the mean body mass index in this study was 22kg/m². This is significantly lower than in contemporary randomised controlled trials (28kg/m²).¹⁵ Third, 'sham' ileal conduits were not fashioned. The effect that an ileal conduit may have on the spread of dye in the anterior abdominal wall could therefore not be fully evaluated. Fourth, it was not possible to inject 20ml of dye into all RSCs, which may have limited the surface area of spread, particularly in cadaver 1. Finally, owing to limitations in the model, the dissection could not be continued into the peritoneum, which may also have had an influence on the results.

Conclusions

This study has demonstrated that posteriorly placed RSCs that have been tunnelled within the space between the rectus muscle and the transversalis fascia (below the arcuate line) are likely to result in optimal spread of local anaesthetic in the nerve supply of the anterior abdominal wall. If it is not possible to place the RSC posteriorly because of surgical factors, then anteriorly positioned RSCs are still able to 'reach' the nerve supply of the anterior abdominal wall and are also likely to provide adequate analgesia.

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