Spanish national survey on the use of cryoanalgesia in the treatment of funnel chest in pediatric patients

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ABSTRACT

Introduction. Pain control following Nuss thoracoplasty remains a challenge. Cryoanalgesia of the intercostal nerves has been demonstrated to reduce postoperative pain in these patients. The objective of this study was to understand how and how widely cryoanalgesia is used in pediatric patients undergoing funnel chest surgery in Spain.

Materials and methods. Nationwide online submission of an author-designed survey.

Results. 18 hospitals replied to the survey. 9 (50%) said they do not use cryoanalgesia, primarily as a result of difficulties in accessing this technique, whereas the other 9 said they do employ it. In most institutions, cryoanalgesia is percutaneous and ultrasound-guided, and it is conducted 1-3 days before surgery (77.8%). The associated use of other analgesic modalities varies widely, including various combinations of intravenous opioid-based PCA (77.8%), epidural catheter (66.7%), oral pregabalin (66.7%), and erector spinae plane block (22.2%). In the institutions where cryoanalgesia is used, mean hospital stay is 4.7 days. Most surgeons believe cryoanalgesia significantly reduces pain in the long-term (88.9%), and only partially in the immediate postoperative period (66.7%).

Conclusions. The use of cryoanalgesia for pain control following Nuss thoracoplasty is an emergent technique. In the Spanish institutions where this technique is used, varying protocols with different associated analgesic modalities can be found.

KEY WORDS: Funnel chest; Minimally invasive surgical procedures; Cryoanesthesia; Pain, postoperative.

ENCUESTA NACIONAL SOBRE EL USO DE LA CRIOANALGESIA EN EL TRATAMIENTO DEL *PECTUS EXCAVATUM* EN PACIENTES PEDIÁTRICOS

RESUMEN

Introducción. El control del dolor tras la toracoplastia de Nuss sigue siendo un desafío. La crioanalgesia de los nervios intercostales ha demostrado reducir el dolor postoperatorio en estos pacientes. El objetivo de este estudio fue conocer la extensión y modo de empleo de la crioanalgesia en pacientes pediátricos intervenidos de *pectus excavatum* en España.

Material y métodos. Envío online a nivel nacional de una encuesta diseñada por los autores.

Resultados. Dieciocho hospitales respondieron al cuestionario. Nueve (50%) declararon no usar crioanalgesia, fundamentalmente por dificultades para el acceso a la técnica. Los otros 9 sí habían incorporado esta modalidad analgésica. En la mayoría de los centros la crioanalgesia se realiza de forma percutánea ecoguiada, 1-3 días antes de la intervención (77,8%). El uso asociado de otras modalidades analgésicas es muy variable, incluyendo diversas combinaciones de PCA de opiáceos intravenosos (77,8%), catéter epidural (66,7%), pregabalina oral (66,7%) o bloqueo de los erectores espinales (22,2%). En los centros que usan crioanalgesia, el tiempo medio de estancia hospitalaria es de 4,7 días. La mayoría de los cirujanos opinan que la crioanalgesia reduce mucho el dolor a largo plazo (88,9%) y solo parcialmente en el postoperatorio inmediato (66,7%).

Conclusiones. El uso de la crioanalgesia para el control del dolor tras la toracoplastia de Nuss es una técnica emergente. Los centros que la utilizan en España, usan protocolos dispares e incorporan diversas modalidades de analgesia asociadas.

PALABRAS CLAVE: *Pectus excavatum*; Cirugía mínimamente invasiva; Crioanalgesia; Dolor postoperatorio

INTRODUCTION

Funnel chest is the most frequent malformation of the chest wall. It refers to the depression of the anterior chest wall, which in severe cases, may lead to cardiac and respiratory functional issues and/or significant cosmetic defects with an impact on psychosocial development. Since it was first described in 1997, minimally invasive repair or Nuss thoracoplasty has been widely accepted as the surgical method of choice to repair the most severe cases, with multiple advantages over open repair[(1)].

In spite of the less invasive approach, pain control following thoracoplasty remains a challenge. Thoracic

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epidural anesthesia has been historically regarded as the gold-standard technique for the treatment of postoperative pain. However, in the last years, the use of other anesthetic techniques reducing potential neurological complications, as well as hospital stay and the need for additional opioids[2-7], has gained traction. Multiple studies have demonstrated the advantages of cryoanalgesia[2,8-17], which inhibits pain perception by temporarily injuring the intercostal nerves with extremely cold temperatures. It is performed using a cryoprobe (–40 to –88ºC) on the intercostal nerves, either ultrasound- or thoracoscopy-guided. Direct contact with cold brings about distortion in the nerve structure and a loss of axonal continuity that leaves the endoneurium, the perineurium, and the epineurium intact, which allows for nerve regeneration. Nerve branch freezing causes the conduction of pain-related impulses to stop, thus producing an analgesic effect that starts in the immediate postoperative period and lasts for weeks or months[18,19].

Thanks to its benefits, multiple institutions have adopted cryoanalgesia as a complement of multimodal pain control regimens following Nuss thoracoplasty. However, there is still no standardized use protocol, and many questions remain unanswered. For instance, there is still uncertainty regarding the most suitable timing for application, or the other analgesic modalities it should be combined with to achieve the best results, with the literature being limited[12,17,20,21].

Based on this context, the primary objective of this study was to describe how and how widely cryoanalgesia is used in pediatric patients undergoing funnel chest surgery in Spain. The secondary objectives were to identify potential hurdles for the use of this technique in certain institutions, to describe the techniques/measures associated with cryoanalgesia in post-thoracoplasty pain control protocols, and to assess its perceived efficacy.

MATERIALS AND METHODS

A descriptive, transversal survey was designed to understand various aspects related to the use of cryoanalgesia in pediatric patients undergoing Nuss thoracoplasty in Spain.

Pediatric surgeons directly involved in the treatment of funnel chest in Spanish hospitals were invited to participate anonymously. Each institution was requested to provide a single, joint response based on regular practice. The survey was distributed to 53 hospitals through the Spanish Pediatric Surgery Society's website (https://secipe.org/wordpress03/index.php/sociedad/encuestas/).

The survey consisted of 27 questions. Demographic data of each institution, integration and use method of cryoanalgesia, use of other pain control modalities/strategies in funnel chest, and objective and subjective assessment of cryoanalgesia results were collected.

Table 1. Number of annual thoracoplasties in the 18 hospitals included in the study.

		N (%)
Annual thoracoplasties	< 5	6 (33.3)
	5-10	5 (27.8)
	10-20	5 (27.8)
	> 20	2 (11.1)

The responses were gathered from August to November 2023 using the Survio website (https://www.survio.com/es/), which specializes in the design and distribution of surveys, as well as in the collection and analysis of their results.

A descriptive analysis of the results was carried out. Qualitative variables were reported as number or percentage of respondents replying to each question, whereas quantitative variables were expressed as mean or median.

RESULTS

18 hospitals replied to the survey, with a response rate of 34% –considering the 53 hospitals registered in the Spanish Pediatric Surgery Society. According to the classification of Spanish public hospitals through the use of cluster analyses[22], half (50%) of the institutions had great structural weight and great activity (group 5), followed by 6 (33.3%) group 3 institutions, and 5 (16.7%) group 4 institutions.

All institutions said minimally invasive surgery is used for the repair of funnel chest today. However, experience was variable, with a median of 12.5 years and a range from 0 to 24 years. The number of annual thoracoplasties per institution is featured in Table 1.

Half (N= 9) of the hospitals that replied to the survey had integrated the use of cryoanalgesia for the management of postoperative pain following Nuss thoracoplasty between 2019 and 2022. The other half said the main causes were difficulties in accessing cryoanalgesia (56%) and lack of specific training (22%). Table 2 features the differences between both hospital groups.

Of the 9 hospitals that do use cryoanalgesia, only 1 reported to have experience with it in other procedures, including pulmonary transplantation and treatment of chest wall tumors and slipping rib. Regarding its use in Nuss thoracoplasty, most institutions apply it on T3-T7 intercostal nerves (66.7%).

In most institutions (66.7%), cryoanalgesia is carried out by a pediatric anesthesiologist using a percutaneous, ultrasound-guided approach. In the remaining ones (33.3%), decision is made on a case-by-case basis, either using a percutaneous, ultrasound-guided approach, or a unilateral or bilateral thoracoscopic approach intraopera-

Table 2. Differential characteristics of the 18 hospitals included in the study regarding the integration or not of cryoanalgesia.

		Cryoanalgesia	
		Yes (N= 9)	*No (N= 9)*
Hospital type	Group 3	2	4
	Group 4	1	2
	Group 5	6	3
Experience with Nuss thoracoplasty (years)	< 5	2	3
	5-10	1	3
	> 10	6	3
Annual thoracoplasties	< 5	1	5
	5-10	3	2
	10-20	3	2
	> 20	2	0

tively. The procedure is conducted 1-3 days before surgery in 77.8% of the hospitals, while in the remaining ones, it is performed on the very same day of the surgery. When asked why, most refer to the literature and/or point to logistic reasons (77.8%). Most groups conduct the procedure in the operating room (77.8%), in a major outpatient surgery regimen (66.7%), and with the patient under sedation (66.7%) or general anesthesia (33.3%).

The use of other analgesic modalities associated with cryoanalgesia for the management of postoperative pain included intravenous opioid-based PCA (77.8%), epidural catheter (66.7%), oral pregabalin (66.7%), and erector spinae plane block (22.2%). The use of these analgesic modalities varied widely among institutions, with various protocols available, ranging from the isolated use of opioid-based PCA (22.2%) or epidural catheter (11%), to various combinations (66.7%) of these modalities –PCA + epidural anesthesia + pregabalin (33.3%), PCA + epidural anesthesia + erector spinae plane block + pregabalin (11%), PCA + erector spinae plane block + pregabalin (11%), and epidural anesthesia + pregabalin (11%) (Fig. 1).

When asked about the integration of non-pharmacological measures for improved recovery in their protocols, 5 out of the 9 institutions (55.6%) mentioned specific rehabilitation programs, whereas only 2 (22.2%) cited follow-up by clinic psychologists.

Most institutions where cryoanalgesia is applied said no cryoanalgesia-related complications have ever been recorded (66.7%). 3 institutions reported pneumothorax and/or mild skin changes. When asked about the approximate duration of cryoanalgesia-related dysesthesia, the mean was 3.75 months (range: 3-6 months).

These institutions reported a mean resuscitation unit stay following thoracoplasty of 1.1 days (range: 0-2), and a mean time to discharge of 4.7 days (range: 3-6). Virtually all surgeons (8/9) said cryoanalgesia had helped reduce mean hospital stay, either on its own (4/8) or combined with the optimization of the postoperative management protocol in their institutions (4/8).

When asked about the subjective perception of postoperative pain reduction, most surgeons said cryoanalgesia significantly reduces pain in the long-term (88.9%), and partially in the immediate postoperative period (66.7%). Only 1 (11%) expressed a different opinion by saying the greatest advantage of cryoanalgesia occurs in the immediate postoperative period.

DISCUSSION

This study provides an overview of the use of cryoanalgesia for pain control following Nuss thoracoplasty in pediatric patients in Spain.

Our results show the integration of this technique has been unequal in Spanish hospitals. In general, the availability of cryoanalgesia was correlated with the type and characteristics of the hospital as it was more frequent in larger institutions with greater experience and more annual thoracoplasties performed. Cryoanalgesia has demonstrated numerous advantages in reducing postoperative pain, opioid requirements, and hospital stay[2,8-17]. This

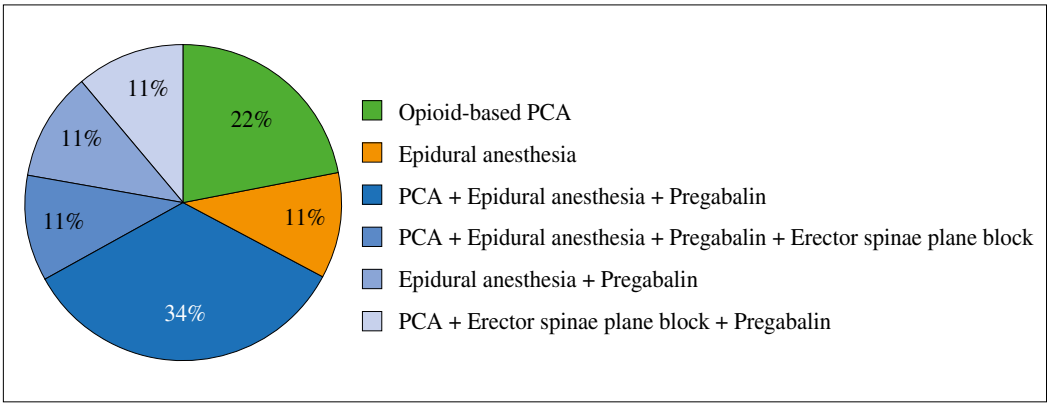

Figure 1. Analgesic modalities associated with cryoanalgesia.

supports the need for ensuring access to cryoanalgesia in all institutions where thoracoplasties are conducted. In addition, most studies on cryoanalgesia-related costs have revealed a reduction in total hospital costs, in spite of the greater equipment and operating time expenses[12,21,23,24].

There are very few literature references exploring the most adequate technique to apply cryoanalgesia on the intercostal nerves. Eldredge and McMahon[12] recently published a literature review on the use of cryoanalgesia in Nuss thoracoplasty. Their findings demonstrated that the thoracoscopic approach and the application of cold in each intercostal nerve for 2 minutes were preferred. However, greater variability was found regarding the number of intercostal nerves treated (4-7 according to the series) and the temperature of the cryoprobe (< –40ºC to –70ºC). Our results show that, in Spain, even though the technique also varies among institutions, the percutaneous ultrasound-guided approach in the 24-72 hours prior to surgery is generally preferred. Various theorical advantages of the ultrasound-guided approach vs. the thoracoscopic one have been suggested[20,21] –for instance, the fact it avoids the additional incisions potentially involved in the thoracoscopic approach and the need for selective intubation and one-lung ventilation to reduce the risk of thermal injury. In addition, this approach allows cryoanalgesia to be applied before surgery, which proves interesting as its effect may take from 6 to more than 24 hours to emerge. In their studies on when percutaneous cryoanalgesia should be applied, Velayos et al.[20,21] concluded that application 24 or 48 hours before surgery seemingly offers better results than on the very same day of surgery. However, it should be noted that the percutaneous approach also has limitations. On the one hand, it requires specific training by the anesthetic team, and on the other, it involves an additional procedure under sedation/anesthesia 1 or few days before thoracoplasty, with the resulting logistic and organizational difficulties.

Regarding the analgesic modalities associated with cryoanalgesia, greater variability was observed. Most Spanish institutions have integrated various combinations of thoracic epidural anesthesia, PCA for administration of intravenous opioids, oral pregabalin, and/or erector spinae plane block in their protocols. None of the respondents reported the use of other documented analgesic techniques, such as transdermal lidocaine or clonidine patches, elastomeric pump or catheters, or regional intercostal nerve block[3,4,6,12].

Deciding which analgesic modalities should be associated with cryoanalgesia to optimize postoperative pain control is complicated. Most publications available just compare the results of cryoanalgesia with control groups using other anesthetic techniques[2,8-10,12-16], which makes it difficult to interpret results and draw evidence-based conclusions. Our results show that, regardless of the analgesic modalities associated, mean time to discharge does not decrease significantly –around 5 days in most institutions. In the last years, various Enhanced Recovery After Surgery (ERAS) protocols to optimize Nuss thoracoplasty patient care have been published[25-28]. The implementation of these protocols has been demonstrated to reduce pain in the immediate postoperative period, thus allowing for the early use of exclusive oral analgesia, and for discharge in the first or second postoperative day. All these protocols apply cryoanalgesia associated with single-injection regional blocks in the intercostal nerves[26,28], in the bilateral serratus anterior plane[27], or in the bilateral paravertebral plane[25]. As previously discussed, the effect of cryoanalgesia may take hours to emerge. Most Spanish surgeons agree that it significantly reduces pain in the long-term and only partially in the immediate postoperative period. In our view, the next efforts should be focused on controlling pain until the effect of cryoanalgesia begins, while exploring the use of anesthetic techniques that may act in this time lapse.

Similarly, the implementation of other measures included in the ERAS protocols, such as avoiding the postoperative bladder probe, promoting early walking, or controlling expectations regarding the recovery process[25-28], should also be considered. Our results show that only certain teams include rehabilitators or clinical psychologists. Specific rehabilitation programs have been demonstrated to improve respiratory parameters even in funnel chest patients not undergoing surgery[29]. Schlatter et al.[5] highlighted the negative impact anxiety may have on patient recovery, underlining how important it is to adequately approach it and redefine expectations at preoperative consultations. In this respect, the role of clinical psychologists or psychiatrists can prove extremely useful.

This study has various limitations. The response rate was 34%, which means responding hospitals may not be a sufficiently representative sample –it should be noted, however, that not all Pediatric Surgery departments conduct funnel chest surgeries. In addition, the fact it was an anonymous clinical practice survey means the experience of the participants or the accuracy of their responses could not be verified, and therefore, the authors cannot guarantee the self-reported data was reliable. Finally, potential selection and response biases should be considered when it comes to result interpretation.

In conclusion, this study provides an overview of the use of cryoanalgesia in the Spanish institutions where Nuss thoracoplasty is conducted in pediatric patients. Cryoanalgesia is an emergent technique that has not been integrated by all institutions yet, in spite of the advantages it has demonstrated in the management of postoperative pain. In the Spanish institutions where it is employed, protocols are unequal, and various associated analgesic modalities are included.

These results demonstrate how important it is to create a standardized, evidence-based protocol in Spain so that clinical practice is unified. Future research should focus on assessing the results of the various pain control protocols

in the context of funnel chest. Multicenter studies aimed at this may solve many of the questions that still remain unanswered.

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