ORIGINAL ARTICLE

DIGITAL THORACIC DRAINAGE SYSTEM: A NEW TOOL FOR PEDIATRIC THORACIC SURGERY

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Abstract

***Introduction**: Digital thoracic drainage systems usage in pediatrics is underreported, making current recommendations based on those for adults. We aim to review our experience on the use of this digital system and to evaluate the adequacy of those recommendations.*

***Methods:** Retrospective analysis of patients in whom digital thoracic drainage system was used. All patients were submitted to thoracoscopic bleb/apical lung resection for primary spontaneous pneumothorax. Initially patients were managed using the few existing recommendations for children, but after 2 unsuccessful cases we changed our approach into tube clamping after continuous air leak < 5mL/min for at least 24 hours.*

***Results:** Seventeen procedures (median 17.2-years) were performed; there were no intraoperative complications. After changing the air leak target, 11 procedures were consecutively managed without complications; the median number of chest radiographs per procedure was 3.0 and the median number of days with chest tube was 4.0 days.*

***Conclusions:** This is the first report on the usage of this system in children in Portugal. This system constitutes an important technological innovation, but it needs more data gathering and prospective trials in order to maximize its use in children. The authors suggest an algorithm for the management of thoracic digital drainage in children: removal of chest tubes when the air leak is <5mL/min for 24 hours and to perform chest tube clamping for a minimum of 6 hours before removal.*

***Keywords:** Pediatrics; Digital Thoracic Drainage; Thoracic Surgical Procedure; Pneumothorax; Air Leak.*

INTRODUCTION

Minor air leaks continue to be the most common complication after lung resection surgery.[1] In spite of being mostly innocuous and amenable to chest tube drainage, currently there is little consensus on its management. The right timing to chest tube removal is also controversial even among experienced surgeons[2], especially when relying on subjective measures such as "bubbles in a chamber" determined in conventional chest drainage.

Digital chest drainage systems have emerged as an alternative that give unbiased information on air leak flow.[1] It facilitates the decision-making process, reducing the risk of misinterpretation and management of air leaks[3], and has also been shown to reduce duration of chest tube drainage and length of hospital stay.[4]

Although its usefulness has been reported in the adult population[4–6], there are currently no specific guidelines for its

use in children. In fact, there are only two reports on its use in pediatric patients.[3,7] The first group suggested chest tube removal in a fully expanded lung when air leak flow is < 10mL/min for 6 hours, as an adaptation from the adult's recommendation of chest tube removal at the presence of an air leak < 30- 40mL/min.[8] The second paper followed those recommendations but extended the air leak threshold for 24 hours. None of the groups performed the provocative clamping test on their series.

The aim of this study is to report our initial experience on the usage of digital chest drainage systems after atypical lung resection surgery for spontaneous pneumothorax in children, the first of its kind in Portugal, and also to highlight some pitfalls on the few recommendations available for its utilization.

MATERIALS AND METHODS

This is a cross-sectional study. We conducted a retrospective study of data of all pediatric patients (aged 0 to 18 years-old) in whom a digital chest drainage system was used after lung resection due to primary spontaneous pneumothorax in our department until June 2021. Patients in whom the digital thoracic system was not applied immediately after surgery were excluded.

Individual patient data was obtained from electronic medical records. Data collected included patient's age and gender, duration of suction (days), duration of drainage (days), number of chest radiographs taken, postoperative air leak-related complications (prolonged air leak and recurrent pneumothorax), and length of stay (days).

All surgical procedures were conducted under general anesthesia with double-lumen intubation. Thoracoscopic (using two 5-mm and one 10-mm trocars) atypical lung resection was done using an endoscopic stapler (60mm ECHELON ENDOPATH™ with gold reloads, Ethicon US), and the presence of an air leak was tested at the end of the procedure by ventilating the submerging lung in sterile saline. Apical pleurectomy or mechanical pleurodesis (according to surgeons' preference) was done in first time surgeries; chemical pleurodesis with talc was done in secondary pneumothoraces and recurrent cases after previous surgery. In the end of the procedure, an apical chest tube was introduced and immediate pleural suction was applied using a digital drainage system (Thopaz+ TM portable digital system, Medela AG, Switzerland). After surgery, a chest radiograph was obtained in the first 4 postoperative hours to verify the drain position and to document lung expansion.

Pleural suction was continuously maintained for at least 48 hours to optimize lung adhesions to the areas of pleurodesis. The pressure used for suction (between -20 and -40cmH2O) was decided according to surgeons' preference. In spite of the previously mentioned recommendations, the provocative clamping test was performed in all patients (during at least 6 hours) after confirmed complete lung expansion on chest radiograph. A target of pleural effusion <1mL/kg per day before chest tube clamping was defined. For air leak monitoring, the reading was done on the digitally produced

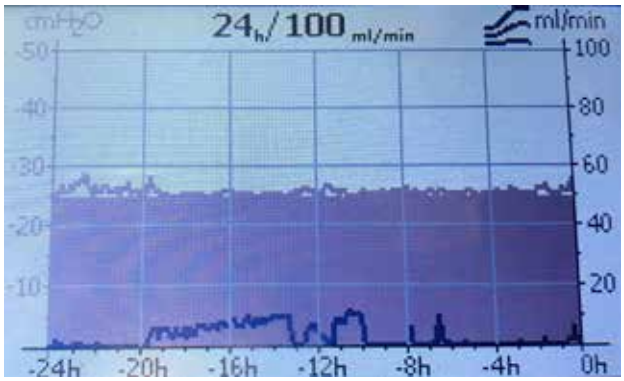

Figure 1 *Digital record of air leak flow <10mL/min during 24 hours.*

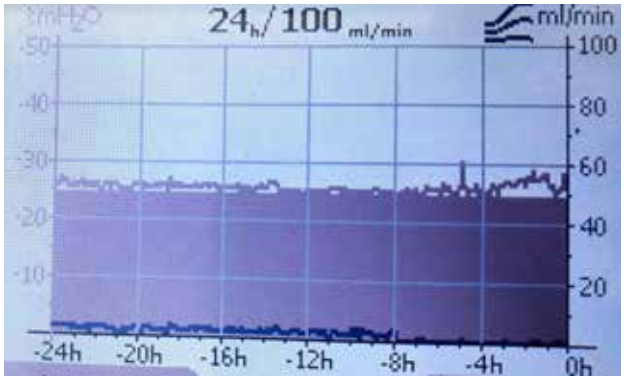

Figure 2 *Digital record of air leak flow <5mL/min during 24 hours.*

graphics (figures 1 and 2). At the beginning of this series, an adaptation from the preexisting recommendations from the two previously published pediatric series was done and the clamping test was done after 12 hours of air leak <10mL/min (figure 1). After failure of this protocol, we changed the limit of air leak to <5mL/min during 24 hours before clamping (figure 2). After clamping, the drain was removed if there were neither clinical nor radiological signs of recurrent pneumothorax for at least 6 hours.

Institutional review board approval was obtained. Collected data from patients is anonymized, so patient consent was not obtained and there were no ethical implications.

A limitation of this study is possible information bias: it is a retrospective study and data concerning clinical features was obtained from the clinical records.

RESULTS

During the mentioned period, Thopaz+ TM system was used after 20 procedures on 14 patients. Three procedures (3 patients) were excluded from data analysis because the system was not used during the immediate postoperative course. This way, data from 17 procedures performed in 11 patients was analyzed. All but two patients were male, aged 17.2 [15.4-17.8] years-old and had no relevant past medical

history. Left and right lungs were affected in 7 and 10 cases respectively.

Patients' management and outcomes are summarized in tables 1 and 2, respectively. Management protocols were adapted according to the development of postoperative air leak-related complications. Only in procedures number 1 and 4, more than one wedge resection was done (2 in each case). One patient (procedures 7-10) presented bilateral relapse after atypical lung resection and pleurectomy, and in the last 2 procedures chemical pleurodesis with talc was done.

All patients presented full lung expansion in the first postoperative chest radiography. In more than half of cases (10/17, 59%), air leak was absent immediately after suction drainage was established in the operating room (procedures number 1, 5, 7-10, 12-13, 16-17); and in the majority of cases (12/17) there was no air leak in the first postoperative day (all procedures but number 3, 6, 14 and 15). Except for procedures number 3 and 6, postoperative drain management was done without complications.

After provocative clamping test, no patient developed any complication (such as dyspnea or cardiac arrhythmia). In two patients we verified recurrent pneumothorax: in the first patient (procedure number 3), the management was done according to the existing recommendations from the previously published pediatric case series, and the chest tube was clamped on the third postoperative day after 12 hours of air flow <10mL/min; however, the chest radiography done 24 hours after clamping revealed a recurrent homolateral pneumothorax, and pleural drainage was restarted; on the fifth postoperative day and after more than 24 hours with air flow nearly 0mL/min, a new provocative clamping test was conducted, and the chest tube was removed the following day after obtaining a normal chest radiography. The second patient with complication (procedure number 6) presented prolonged postoperative air leak; on the 13th postoperative day, the digital device showed an air leak <10mL/min during 24 hours, and so provocative clamping was done; however, chest radiograph 24 hours later revealed recurrent homolateral pneumothorax, and pleural drainage was resumed; on the 20th postoperative day, chest tube clamping was attempted again after 30 hours of air leak <10mL/min, but a recurrent pneumothorax developed once again; the patient was eventually submitted to autologous blood patch that complicated with empyema and was further submitted to thoracoscopic lung decortication, with successful resolution and discharge 55 days after the initial intervention.

After the implementation of the adjusted protocol (last 11 procedures) the median number of chest radiographs was 3.0 [2-5], the median number of days with chest tube was 4 [3-8] days, and the median length of stay was 4.5 [3-8] days (table 3).

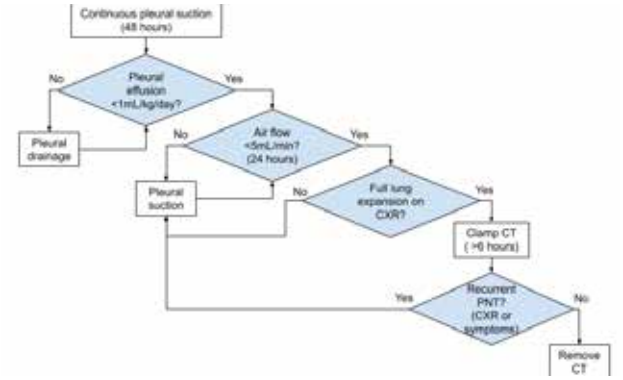

Figure 3 *Proposed algorithm for management after lung resection surgery in children. CT, chest tube; CXR, chest radiography; PNT, pneumothorax.*

DISCUSSION

Air leak remains an important postoperative feature after lung resection. It can cause increased morbidity due to complications such as pneumonia, subcutaneous emphysema, atrial fibrillation and increased hospital stay. [5]

For a long time, the evaluation of air leak was based on static and subjective measures (such as "bubbles in a chamber"), and it lacked agreement even among experienced clinicians. [2] Digital systems were developed in order to simplify this clinical parameter for more precise measurements of air leaks. Since its development, several studies have shown that digital chest drainage is associated with shorter chest tube duration, decreased number of postoperative chest radiographs, shorter hospital stay, lower risk of postoperative complications, and more consistent and objective readings of air leaks when compared to "bubble" devices. [6,7,9] Moreover, this portable system allows patients to be significantly more mobile when compared to patients who are treated with wall suction drainage. [10]

Currently, air leak management based on information from digital systems differ among surgeons. In 2011, a consensus on the management of the pleural space stated that chest tube removal was safe in the presence of an air flow <40mL/min during 6-8 hours with a plateau or a sloping down trend. [8] Later in 2014, a multicenter study recommended chest tube removal when air flow was <30mL/min for at least 8 hours and without significant oscillations. [11]

However, and as highlighted by a review in 2019, evidence for the use of digital thoracic drainage systems in the pediatric population is lacking.[4] In fact, there are currently only 2 papers on pediatric series using digital thoracic drainage systems, both using theThopaz+ TM device: in 2016, Costa et. al defined air leak flow <10mL/min for 6 hours as the threshold for chest tube removal [3]; then later in 2019, the group of Pérez-Egido et. al proceeded to chest drain removal when air leak flow was <10mL/min for 24 hours and after obtaining a chest radiograph with complete lung expansion.[7] These recommendations were probably based on the adults' recommendations and not in any available clinical evidence in the pediatric age.

In our department, we started to use the Thopaz+ TM's system in with an intermediate threshold: with a complete lung expansion on chest radiograph, we aimed for air

Table 1 **Patients' management.**

Procedure Number	Age (years), Gender	Affected lung	Pleural procedure	Maximum suction pressure (cmH2O)	Air leak before clamping (mL/min; hours)	Postoperative complications
1	17, M	Left	Pleurectomy	-20	<10mL/min; 12h	no
2		Right	Pleurectomy	-20	<10mL/min; 12h	no
3	15, M	Right	Mechanical pleurodesis	-40	<10mL/min; 12h	Recurrent pneumothorax*
4	17, M	Left	Chemical pleurodesis	-40	<10mL/min; 24h	no
5	17, M	Right	Mechanical pleurodesis	-40	<10mL/min; 24h	no
6	16, F	Right	Mechanical pleurodesis	-20	<10mL/min; 24h	Recurrent pneumothorax**
7	16, M	Left	Pleurectomy	-20	<5mL/min; 24h	no
8		Right	Pleurectomy	-20	<5mL/min; 24h	no
9		Left	Chemical pleurodesis	-40	<5mL/min; 24h	no
10		Right	Chemical pleurodesis	-40	<5mL/min; 24h	no
11	17, M	Left	Mechanical pleurodesis	-20	<5mL/min; 24h	no
12	16, M	Left	Pleurectomy	-20	<5mL/min; 24h	no
13		Right	Pleurectomy	-20	<5mL/min; 24h	no
14	17, M	Left	Pleurectomy	-20	<5mL/min; 24h	no
15		Right	Pleurectomy	-20	<5mL/min; 24h	no
16	16, M	Right	Pleurectomy	-20	<5mL/min; 24h	no
17	17, F	Right	Mechanical pleurodesis	-20	<5mL/min; 24h	no

F, female; M, male; max, maximum
** Management was changed after this patient: the goal started to be an air leak < 10mL/min but for 24 hours*
*** Management was changed for the second time after this patient: the goal started to be an air leak < 5mL/min for 24 hours.*

leak <10mL/min (figure 1) during at least 12 hours before chest tube clamping. However, this proved to be inefficient in two patients. Based on this experience, we changed the management protocol for a limit of air leak <5mL/min for 24 hours directly read on the machine's graphical representation (figure 2) before chest tube clamping; all these cases were managed successfully and without complications.

Provocative tube clamping was general practice after lung resection surgery. We decided to maintain this practice after we started using digital drainage systems because we wanted to avoid the need for a new chest tube emergent insertion in these patients that do not tolerate this procedure under local anesthesia as well as adults.

When debating why such a different cut-off may be necessary to safely manage these patients, the authors think it may be due to the nature of the disease these patients suffer: spontaneous pneumothoraces typically occur due to the presence of fragile emphysematous lung parenchyma where blebs are formed. This way, after doing an atypical resection using automatic staplers, this fragile parenchyma can take longer to heal and be more prone to sustain subtle air leaks when compared, for instance, to lobectomies where the sectioned lung parenchyma is more robust (and sometimes not even divided if lung fissures are complete).[12] Maybe that is why a lower threshold for air leak is needed in teenage patients after surgeries for their spontaneous pneumothoraces.

In the instructions for use manual of the Thopaz+ TM drainage, the interpretation of the graphics is explained: air flow of 0-4mL/min is displayed on the screen as 0mL/min; air flow of 5-14mL/min is shown as 10mL/min; air flow of 15-24mL/min is expressed as 20mL/min (and forward using 10mL steps). These technical aspects are important to stress, since a display of an air flow equal to 0mL/min does not correspond to an absolute absence of air leak.

In light of the available data and acquired experience, we suggest an algorithm for the management of postoperative air leak in children using digital thoracic drainage systems (figure 3). It is based on 4 essential cumulative goals: i) complete lung expansion on chest radiograph; ii) pleural effusion <1mL/kg/day; iii) air leak flow <5mL/min for 24 hours (readings on the digital generated graphics); and iv) no clinical/radiographic recurrence after provocative clamping test.

The results of the last 11 procedures of our series shown in table 3 reveal that the median number of chest ra-

diographs, days with chest tube in situ and patients' length of stay are in accordance with previously published data. [6,7] The aim of our protocol's adaptation was accomplished: it does not increase patients' exposure to radiation nor length of stay but, contrary to the previous suggested approaches [3,7] that were not adequate for two patients in our series, does improve safety while using Thopaz+ TM's and potentially reduces the need of an urgent/emergent re-drainage.

Our study has some limitations: its retrospective nature and small number of patients reinforce future prospective studies should be conducted to further validate this data. We also suggest that Medela® should develop an adapted scale for pediatric patients in order to facilitate readings of 5mL/min in air leak graphics.

Further data gathering of subsequent patients is being done in order to update our knowledge and optimize the management of these patients.Questions such as the utility of provocative clamping test in the era of digital thoracic drainage and if body habitus plays a role in the risk of developing prolonged air leak remain unanswered and need investigation.

CONCLUSION

This is the first report on the usage of digital thoracic drainage systems in children in Portugal. These systems constitute an important technological advance in thoracic surgery and seem valid and adequate. However, more data gathering and prospective trials are needed in order to solidify its role in pediatric thoracic surgery. For the moment, we recommend obtaining an air leak flow <5 mL/min for 24 hours and perform the provocative clamping test before chest tube removal to make sure there is no residual air fistula.

Table 2 **Outcomes of all patients (n=17).**

	Min	Q1	Median	Q3	Max
Air leak duration, days	0	0	0	1.0	28
Pleural suction duration, days	2	2.0	3.0	3.0	40
Chest drainage duration, days	3	3.0	4.0	4.0	41
Number of chest radiographs	2	2.0	3.0	4.0	27
Length of stay, days	3	3.0	5.0	6.0	55

Max, maximum; Min, minimum; Q1, first quartile; Q3, third quartile

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