Implementing thoracoscopic lobectomy in pediatric surgery practice using the master-apprentice approach

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Submitted
Abstract

Getting safely through the learning curve for specific operations in pediatric minimal invasive surgery is challenging. Thoracoscopic lobectomy (TL) is a highly demanding operation in children and has several advantages compared to open lobectomy (OL). But implementation of this technique could be arduous. A program using the master-apprentice model (MAM) was started to implement this highly advanced thoracoscopic technique as safely as possible in our hospital.

Aim. To analyse the results obtained during the implementation process of TL using the MAM. The process is described and the results will be compared with OL from our institution to judge if continuation of TL is legitimate.

Methods. Thirteen TL patients (2009 - 2012) and 17 OL patients (1987 - 2012) were retrospectively compared. Indications were sequestration and congenital pulmonary airway malformation (CPAM). The process of implementation, description of the operative procedure and characteristics of MAM were extensively described.

Results: Operation time was longer in the TL group (median 173 minutes TL vs 143 OL) and length of stay in TL patients (median 3 days) was shorter than in the OL group (median 5 days). Duration of chest tube drainage was shorter in the TL group (2 versus 3 days). There were two complications in the TL group and seven in the OL group, but the two groups were not in all aspects comparable.

Conclusion: Implementation of thoracoscopic lobectomies using the Master Apprentice Model is safe and the obtained results justify the continuation of TL.
Background

As minimally invasive surgery is becoming more widespread in daily surgical practice around the globe, surgeons are confronted with more difficult and more advanced operations they have to learn. Doing so they are getting through the learning curve for the specific operations they have to master. These procedures have their own specific challenges and aspects. However, there are scarce numbers of studies with exact numbers regarding the learning curve or recommendations how to deal with this process 1, 2.

There are several different tools which can be used to teach new surgical procedures. The master apprentice model (MAM) is the cornerstone in surgical education. Working with the MAM is a known method in training residents and changed in history from a rigid situation into a mutual stimulating relationship3. Although the positive development of box trainers and virtual reality simulators, the hands-on training on a real patient with an experienced surgeon at the trainee’s side still remains the most important element in training a specific operation 4.

With the development of box trainers and virtual reality training, surgical residents are able to learn knotting and suturing before performing endoscopic procedures on humans. Incorporated in a curriculum it significantly improved the residents skills 5, 6. Also in pediatric surgery this phenomenon is important because of patient safety concerns. Teaching residents and fellows new techniques should be done in an optimal way.

However, in pediatric minimal invasive surgery there are additional challenges related to the specific nature of the pediatric patients and their pathology. The size of the patient and the degree of motion-scaling is different. Smaller equipment and areas of dissection together with greater optical magnification requires finer dissection skills 7. The known box trainers and virtual reality simulators at date are for training basic skills and advanced procedures such as laparoscopic colectomy in adult surgery 6.

For more advanced and highly advanced procedures, such as thoracoscopic lobectomy, there are neither virtual reality simulators nor good box trainers available to incorporate in a curriculum. Implementation of highly advanced procedures is therefore complex and requires special attention. The low volume aspect of this complex procedure entails the need for a dedicated surgical team.

Lobectomy performed by minimal invasive surgery has several advantages compared to open lobectomy, i.e. a shorter length of stay and a shorter duration of chest tube drainage without increased complication rate 8. In our opinion, thoracoscopic lobectomy is the procedure of choice. However, due to the above mentioned limitations (i.e. lack of virtual reality trainer, low volume) implementation of this technique could be arduous. For that reason, a program using the master-apprentice model was started to implement this highly advanced thoracoscopic technique as safely as possible in our hospital. The implementation of a new minimal invasive operation can be seen as an example of continuous medical education (CME). In minimal invasive surgery there is a great importance of CME as
already stated earlier by Soper. In this situation with an experienced staff surgeon as the apprentice, the concept of MAM, in minimal invasive surgery, could still be very useful.

Aim

The aim of this study is to analyse the results obtained during the implementation process of thoracoscopic lobectomy using the master apprentice model. The process will be extensively described and the results will be compared with the results from open lobectomy from our institution to judge if continuation of thoracoscopic lobectomy is legitimate.

Patients and methods

Patients

The results of the first 13 thoracoscopic lobectomies were retrospectively compared with 17 open lobectomies. The thoracoscopic lobectomies were performed between 2009 and 2012 and the open lobectomies were performed from 1987 until 2012. Indications for the thoracoscopic resections were sequestrations (n=3) and congenital pulmonary airway malformation (CPAM) (n=10). Indications for open lobectomies were sequestrations (n=1) and congenital pulmonary airway malformation (CPAM) (n=16). In 92% (12/13) of the thoracoscopic operations, the patients were asymptomatic. In these patients, the diagnosis was made by prenatal ultrasound and confirmed by CT scan with IV contrast at the age of 3-6 months. The CT scan was also used to analyse anatomical variations such as abdominal artery supply in sequestrations to facilitate preoperative planning. In 9 of the 17 open procedures, the indication was symptoms of respiratory distress (n=3), infections (n=6) or no symptoms (n=8). See also table 1. The two groups were compared on demographics, operating time, complications and length of stay. Analysis was done with IBM SPSS statistics 19.

Process of implementation

Besides these clinical outcomes we want to share our experiences and considerations of the master-apprentice model. The operations were done by the first author, an experienced surgeon in minimal invasive pediatric surgery and open lobectomies, as apprentice and a surgeon from another institution, known as an expert in minimal invasive surgery, as master.
Description of the operative procedure

The thoracoscopic operation was performed with 3 trocarts using 3 mm or 5 mm instruments depending on the age of the patient. At least one 5 mm trocart was used for the introduction of the ligasure LS 1000®, mandatory for taking down the pulmonary vessels. After creating a pneumothorax and introduction of the trocarts, the interlobar fissure was developed when incomplete and the pulmonary vein was dissected but not sealed. In the fissure the pulmonary arteries were taken down followed by the pulmonary vein. The bronchus was isolated, divided and closed with a watertight stitch that was tested on air leakage. A chest tube was placed and by enlarging one trocart-site to 10 or max 15 mm the specimen could be taken out.

Open lobectomy was performed via a posterolateral, muscle-sparing thoracotomy, but otherwise according to the same principles as outlined above.

The chest tube was removed after a standardized clamping procedure. Patients were discharged after removal of the chest tube, when full oral feeds were possible and no IV fluid administration was needed.

Description of the master apprentice model

In our setting the master (H.S.) is a dedicated expert in minimal invasive procedures such as thoracoscopic lobectomies. The apprentice (M.O.) is a dedicated minimally invasive surgeon with experience in open lobectomies but lacking in experience in thoracoscopic lobectomies.

The apprentice was already confident with the dissection techniques and the use of a device as the ligasure, LS 1000® which is mandatory to fulfil the operation via the minimally invasive approach. This 5 mm instrument is suitable for dissecting and coagulating the pulmonary vessels but not for dividing them. Experience with open lobectomies enabled the apprentice to convert the thoracoscopy to open approach if necessary. The specific role of the master was to guide the apprentice in complications and difficulties as bleeding and handling aberrant anatomy via the minimal access route.

Before starting the implementation of the thoracoscopic lobectomy the apprentice made working visits to several experts around the world and one of them was contacted to collaborate.

The apprentice prepared himself by watching videos on the specific procedure, for example right lower lobe (RLL) lobectomy, available on the internet like Websurg®.

Although there are no formal guidelines for performing this operation the apprentice made a step wise procedure on paper. In the specific example of a RLL lobectomy the following surgical steps were identified:

1. Introduction of the first trocart midaxillairy at 5/6th intercostal space, creation of pneumothorax with low pressure (4 mmHg) and flow (1L/min)
2. Identification of the anatomy; the lobe with CPAM and the major fissure
3. Mobilisation of the inferior pulmonary ligament
4. In case of an incomplete fissure, completion of the fissure with LS 1000.
5. Isolation of the pulmonary artery and double-seal with LS 1000
6. Division of the artery
7. Isolation of the pulmonary vein and double-seal with LS 1000.
8. Division of the vein.
9. Isolation of the bronchus and division sharply.
10. Closure of the stump of the bronchus with PDS on a RB-1 needle.

The first operation was performed by the master with the apprentice as assistant. The next operation the apprentice performed the operation and the master was assisting. After that the master would be in the operating theater while the apprentice performed the operation with a staff surgeon as assistant. During these procedures, the master provided only feedback, as it is more effective that the pupil is doing the task. 

Results

Thoracoscopic

In 13 patients a total of 15 minimal invasive procedures were performed (2 boys and 11 girls).

Nine lobectomies were executed with a median operating time of 173 min. In one patient a bilobectomy was performed. All lobectomies were done for CPAM. For sequestration one segmentectomy, one lingulectomy and one extralobar resection was done. There was no conversion to thoracotomy (Table 1).

Table 1. Results of performed procedures, CPAM: Congenital Pulmonary Airway Malformation, LOS: Length Of Stay.

|                        | Thoracoscopic (n=13) | Open (n=17) |
|------------------------|----------------------|-------------|
| Male:Female            | 02:11                | 07:10       |
| Median age at surgery  | 395 dd (121dd-2.7yrs)| 192 dd (1day-16.2 yrs) |
| Procedures             | Lobectomy 9          | Lobectomy 14 |
|                        | Bilobectomy 1        | Bilobectomy 1 |
|                        | Segmentectomy 1      | Lobectomy 1 |
|                        | Lingulectomy 1       | Lobectomy +segmentectomy 2 |
|                        | Extralobar resection 1 |           |
| Indication             | CPAM 10              | CPAM 16     |
|                        | Sequestration 3      | Sequestration 1 |
| Median operating time  | 173(80-306)          | 143(79-260) |
| (range)                |                      |             |
| Median LOS (in days)   | 3 (2-5)              | 5 (3-24)    |
| Median duration of drain in days (range) | 2(0-4) | 3(2-10) |
| Complications          | 2                    | 7           |
There were two complications, one urinary tract infection in a patient with CPAM. And one patient who underwent a segmentectomy for sequestration developed a pulmonary abscess which was treated successfully with radiological guided drainage and antibiotics. For this the patient was readmitted in the hospital as fever was noted 10 days after discharge. Median length of stay was three days and median duration of the chest tube drainage was two days.

**Open**

In the historical open group there were 7 boys and 10 girls. The median operating time was 143 min. Sixteen lobectomies were done, once a bilobectomy and in two patients a lobectomy combined with a segmentectomy was performed. Except one patient with intralobar sequestration all the patients were operated on for CPAM. In 7 of the 17 patients there was a complication. In five cases (pneumonia, atelectasis, prolonged air leak from chest tube, blood loss of 420 ml and viral upper airway infection) it resolved without reoperation but in two cases an intervention was necessary. One patient had a postoperative bleeding for which a new thoracotomy was necessary and in one case a tension pneumothorax necessitating a second chest tube drainage. Median length of stay was five days and median duration of the chest tube drainage was three days.

**Discussion**

In this study, the implementation of the thoracoscopic lobectomy using the Master-Apprentice model has been described and analysed. When comparing the results of the two groups fewer complications, shorter length of stay and shorter duration of chest tube drainage were found in favour of the thoracoscopic group and less operating time in the thoracotomy group. These results favour the continuation of performing thoracoscopic lobectomies.

Although there was no significant difference in the age at operation between the two groups they are not comparable because of difference in clinical condition due to the mode of presentation as the patients in the thoracoscopic group were all asymptomatic except one and the historical group consisted in 8 out of 17 in symptomatic patients. A further shortcoming of this study is its small sample size. Other comparative studies with adequate comparable groups show that TL is feasible and safe but with longer operation time and shorter length of stay in comparison with OL \(^{10, 11, 12}\). But these series also contain a high conversion rate (Vu 6 of 18 TL, Diamond 2 out of 12) which could have been influenced by the learning curve \(^{12}\). None of these papers describe the implementation of the TL, a procedure which they compared with
OL. Although in this current study, after 13 TL, it seems not justified to identify a learning curve since the number of patients is limited. But with the use of MAM no conversions did occur in this series which can contribute to finish the learning curve earlier. In the future identification of the learning curve in TL could be achieved.

There are several stages in the development and assessment of surgical innovations as described by the Balliol Collaboration. In their article they present the IDEAL recommendations as a model for the implementation of a surgical innovation. Step 1 is when a procedure is done by pioneers or innovators, step 2a when the procedure is further developed and step 2b when the procedure has been perfected and the surgical community learns how best to use the intervention. Afterwards reports are published about feasibility and safety. In step 3 RCT’s are done to assess effectiveness against current standards and in step 4 the procedure is assessed for long-term and variations in outcome.

Based on the available literature thoracoscopic lobectomies are in stage 2b now, there are multiple reports on feasibility and some retrospective comparing reports but no RCT’s. In this stage the issue of mentoring and learning-curve evaluation is important. In our opinion the master-apprentice model is therefore still valuable in pediatric thoracoscopic lobectomies. Also in adult VATS lobectomy the learning curve is done in a master-apprentice model.

Box models and VR are suitable for basic training in residents and advanced laparoscopic procedures in adults. But no box models or VR programs to date are suitable for teaching of and training in thoracoscopic lobectomies in children. Interesting in this matter are the studies from van Det and Wentink in which Rasmussen’s model and the applicability in teaching laparoscopic surgery is described. Rasmussen’s model of human behaviour consists of three levels of competence that have to be trained, skills-level, rule level and knowledge level. Skills are the instrumental handling and dissection techniques and rule behaviour is the recognition of the surgical anatomy. The apprentice is, with the experience of the specific instruments as the LS 1000, competent at the skill level and the experience in anatomy from open lobectomies made the apprentice competent at rule level. When facing a complication as a bleeding or an aberrant surgical anatomy, the problem needs to be solved at a knowledge-based level. In this the specific role of the experienced master is needed as for example in the execution of controlling a bleeding or in the case of aberrant (abnormal) anatomy of a patient with CPAM which contained an intralobar sequestration in the same lobe. A problem that possibly could lead to conversion can be managed minimal invasively.

The antenatally improved imaging is confronting us nowadays with more congenital pulmonary malformations than during the past when open lobectomies were done. This series shows that thoracoscopic lobectomy, as highly advanced minimally invasive procedure can be taught safely using the master-apprentice model. Preferably this model is used with patients from collaborating hospitals to increase the volume to pass the learning
curve quicker and better to eventually define it objectively, e.g. the number of operations to perform it safely without risk for the patient and might even in difficult cases lower the conversion rate to thoracotomy. After that a prospective comparative study can be done to get this surgical innovation to a higher level in the IDEAL-recommendation.
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