SURGERY FOR CONGENITAL HEART DISEASE

VIDEO-ASSISTED THORACOSCOPIC SURGICAL INTERRUPTION: THE TECHNIQUE OF CHOICE FOR PATENT DUCTUS ARTERIOSUS

Routine experience in 230
pediatric cases

Video-assisted thoracoscopic surgical interruption for patent ductus arteriosus is a well-standardized procedure already described. We present our entire series of such cases, from the first case (performed on Sept. 5, 1991) to March 1, 1995. Two hundred thirty patients in a variety of age groups underwent video-assisted interruption: younger than 6 months (70 patients, 30%), 6 to 48 months (123 patients, 54%), and older than 48 months (37 patients, 16%). The mean weight was 12.6 kg (range 1.2 to 65 kg). Thirty-nine patients had symptomatic pulmonary hypertension. Associated intracardiac anomalies included atrial septal defect (three), ventricular septal defect (five), and anomalous pulmonary venous return (one). All patients underwent video-assisted interruption of the patent ductus arteriosus with two titanium clips. Closure was evaluated by postoperative echocardiography before extubation. Five patients had a persistent patent ductus after video-assisted interruption, all early in our experience and related to insufficient dissection resulting in inadequate clip placement. Four patients had successful immediate clip repositioning (three by video-assisted interruption and one by thoracotomy). Subsequent echocardiography revealed persistent closure in these patients. A persistent patent ductus arteriosus with minimal flow was discovered in one patient without symptoms after discharge. Recurrent laryngeal nerve dysfunction was noted in six patients (2.6%; five transient and one persistent). There were no deaths, hemorrhages, transfusions required, or chylothoraces in this series. Mean operative time was 20 ± 15 minutes, and hospital stay averaged 48 hours for patients younger than 6 months and 72 hours for patients older than 6 months. This is a safe, rapid, cost-effective technique that results in excellent results and a shortened hospital stay. Video-assisted interruption represents the technique of choice for closure of a patent ductus arteriosus. (J THORAC CARDIOVASC SURG 1995;110:1681-5)

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Patent ductus arteriosus (PDA) was first surgically ligated in 1939 by Gross and Hubbard.¹ Since then, several techniques of PDA closure have been described, such as simple ligation, multiple trans-fixed ligatures, titanium clipping occlusion, suture and division, as well as recently transcatheter closure. A new technique of video-assisted thoracoscopic surgical (VATS) interruption of PDA was described by us elsewhere in 1993.² This technique

Fig. 1. Illustration showing ports and instruments for VATSI of a PDA.

has been subsequently extended to division of vascular rings, interruption of arterial and venous collateral vessels, and PDA interruption in the premature infant.^{3,4} Since our initial report, we have continued to use this method exclusively for PDA closure, except for patients undergoing a congenital cardiac procedure with an associated PDA. In these cases, the PDA is closed with division and suture during the associated procedure. We report here our entire experience with VATSI.

Patients and methods

All patients undergoing VATSI, from the first case (performed on Sept. 5, 1991) to March 1, 1995, were reviewed. All procedures were performed by the same surgeon (F. L.) in the same institution. Preoperative data included age, sex, weight, symptomatic pulmonary hypertension, and associated intracardiac anomalies. Intraoperative data included mean operative time and mean hospital stay. All complications related to the procedure were recorded.

All infants and children sent to Centre Chirurgial de la Porte de Choisy for closure of PDA underwent VATSI closure unless PDA was part of a more complex congenital cardiac lesion requiring either cardiopulmonary bypass or a closed-heart palliative procedure. Informed consent was obtained from all parents, and the procedure received approval from the local ethics committee.

Anesthesia. General anesthesia is performed with pentothal at a dose of 5 to 10 mg/kg, vecuronium (Norcuron) at a dose of 0.1 mg/kg, fentanyl at a dose of 5 µg/kg, and 1% to 2% enflurane (Ethrane).

Procedure. After induction of general anesthesia and intubation, the patient is positioned on his or her right

side, as for a posterolateral thoracotomy. Two thoracostomies 5 to 7 mm long are made in the left hemithorax, each corresponding in size to the appropriate instruments for that position: one through the posterior part of the third intercostal space, for the videothoracoscope, and one through the fourth intercostal space on the axillary line, for the introduction of surgical instruments. One or two 60 degree angled-hooks, 1 mm in diameter, are introduced through the third intercostal space in its middle part for lung retraction (Fig. 1).

Instruments used for VATSI include scissors, dissectors, electrocautery hooks, a clip applicator, a lung retractor, and a suction device. The surgical field is viewed on a video screen by means of a video camera and can be stored on a video recorder.

The upper lobe of the left lung is retracted inferomedially, the PDA is identified, and the mediastinal pleura is opened with cautery nerve hook. The PDA is dissected from surrounding tissues, and the aorta is dissected at its junction with the PDA. The pericardium is dissected on the pulmonary side to protect the recurrent laryngeal nerve from any traumatic injury. It is essential to dissect on both sides of the PDA to place the clip adequately. The clip applicator is then introduced through the posterior thoracostomy. A first titanium clip (9 mm) is placed as distal as possible from the aortic junction, and a second titanium clip is applied on the side close to the aorta. After visual confirmation that both clips are well in place, the lung is inflated and a 2 mm diameter pleural suction catheter is placed before closure of the 5 mm skin incisions with sutures. The catheter is removed after a postoperative chest radiograph has been obtained.

Color-flow Doppler echocardiography is performed in the recovery room before extubation to assess the completeness of closure of the PDA. If there is a residual shunt, the patient is taken back to the operating room for another VATSI. Otherwise, the patient is extubated if there are no contraindications to extubation. Patient's are placed either in the intensive care unit or in a regular pediatric room, according to age and previous symptoms of pulmonary hypertension. All patients are seen after operation by a pediatric cardiologist, and transthoracic echocardiography is performed on the day of discharge. All patients are then regularly followed up by their own pediatric cardiologists, who perform a complete physical and transthoracic examination.

Results

Patients. Two hundred thirty patients underwent VATSI of PDA at our institution. Patients were divided into three age groups: younger than 6 months (70 patients, 30%), 6 to 48 months (123 patients, 54%), and older than 48 months (37 patients, 16%). The mean weight for the entire series was 12.6 kg (range 1.2 to 65 kg), with three patients weighing less than 1.9 kg (1.8, 1.3, and 1.2). Thirty-five patients had symptomatic pulmonary hypertension, most in the group younger than 6 months; the remainder were free of symptoms. Associated intra-

cardiac anomalies included atrial septal defect (three), ventricular septal defect (five), and anomalous pulmonary venous return (1). The mean operating time for the last 200 patients was 20 mn $\pm$ 15 mn. Operating room time is from the time of incision to the skin closure.

Complications (Table I). Five patients had a persistent PDA after VATSI, all early in our experience and related to insufficient dissection resulting in inadequate clip placement. Four patients had immediate clip repositioning (three by VATSI and one by thoracotomy). Subsequent echocardiography revealed complete closure in these patients. A persistent PDA with minimal flow was discovered in one patient without symptoms after discharge. This patient is being regularly followed up by echocardiography with no increase in flow. Three patients had VATSI after an attempt at percutaneous catheter closure (Rashkind double-disk umbrella occluder device), with the device in place and a persistent shunt. All three attempts were successful, with no residual flow seen by echocardiography.

Recurrent laryngeal nerve dysfunction was noted in six patients (2.6%; five transient and one persistent) evaluated by postoperative laryngoscopy. There were no deaths, hemorrhages, transfusions required, or episodes of chylothorax. Four episodes of pneumothorax occurred in our eight initial patients, who did not have chest tube drainage.

Length of stay. The median length of stay for patients younger than 6 months was 72 ± 24 hours; it was 48 ± 24 hours for patients older than 6 months. All premature infants were returned to their original intensive care units after removal of the chest tube.

Discussion

Surgical closure of PDA is now well standardized and provides excellent results, with low mortality and morbidity. Most older patients have division of the ductus through a thoracotomy, whereas infants undergo closure with a clip. Surgical closure of the PDA in the neonatal intensive care unit has been described, with excellent results.⁵⁻¹⁰ The procedure consists of placement of one or two clips through a thoracotomy, generally with an extrapleural approach. The advantages given are its low morbidity, lack of mortality, and reliable PDA closure. The application of metal clips near the aorta reduces the risk of recurrent laryngeal nerve injury and does not require com-

Table I. Results of VATSI

Patients (no.)	230
Residual patency (no.)	5 (2.1%)
Recurrent laryngeal dysfunction (no.)	6 (2.6%)
Postoperative stay (hr)	
Patients >6 months	48 ± 24
Patients <6 months	72 ± 24
Operating room time (min)	20 ± 15
Deaths	0

plete mobilization of the ductus, reducing the risk of surgical bleeding.

Our technique of PDA closure by VATSI² provides the same results without a thoracotomy. This technique is simple and safe, and it becomes quite expedient with good practice. Although five patients in our series had a persistent shunt after VATSI, none occurred in our last 200 patients. It is extremely important to dissect both sides of the ductus adequately to place the clips.

Four patients had a pneumothorax after the procedure; we did not see any occurrence of pneumothorax after we initiated chest tube drainage. The main complication was transient paralysis of the left vocal cord (2.6%). This can also be seen after open surgical interruption of the ductus, with the same incidence.¹¹ Risks factors generally given are low weight (less than 1500 gm) and extensive dissection around the ductus. We believe that minimal dissection around the ductus should be performed to avoid this complication.

Percutaneous catheter closure of PDA has been described elsewhere.¹²⁻¹⁴ The advantages offered are avoidance of any incision and lack of general anesthesia, although intravenous sedation is usually given. Many groups still perform general anesthesia however, because since the duration of the procedure can sometimes exceed that required for operative treatment. The main disadvantage remains persistent shunting, on the order of 27% at 6-week follow-up, which decreases generally between 10% and 20% at 6 months. Persistent shunting increases with the size of the ductus. Possible migration or embolization of the device may necessitate surgical removal. Also reported are hemolysis and the problem of prophylaxis against bacterial endocarditis in residual shunts. In addition, this technique is applicable only for patients weighing more than 10 kg because the size of these small vessels makes the use of the device difficult. In addition, recent results showing superiority of surgical versus transcatheter closure for outcome and cost, VATSI probably can

reduce the hospital cost even further.¹⁵ Only a prospective trial comparing all alternatives can clarify the issue.

The technique of VTSI can also be performed in premature infants, as we and others have demonstrated with excellent results and no morbidity.^{3,4} The procedure is rapidly performed, with an average of 15 to 20 minutes. No complications related to the procedure have been reported in this age group as yet. We therefore believe that this technique can be safely applied to premature infants.

The only contraindication to this procedure is if the diameter of the ductus is greater than the size of the clip (9 mm) or if the ductus is calcified. Both of these situations can be encountered in older children or adults. In children, the only contraindication would be a previous thoracotomy with pleural adhesions. Video-assisted thoracoscopy in children can also be extended to other procedures, as described elsewhere.³

In our series, we had no cases of chylothorax, hemorrhage, blood loss, phrenic nerve injury, or in-hospital infection. There were no deaths related to the procedure. Prospective efforts must be made to demonstrate reductions in cost, pulmonary injury, and hospital stay. We conclude that the technique described here is safe and rapid, can be practiced with little morbidity, and can be learned easily.

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Discussion

Dr. Redmond Paul Burke (Boston, Mass.). At Children's Hospital in Boston we now consider the video-assisted approach to PDA the primary therapeutic approach in elective cases and in premature patients. We have comparable results to yours, with a wide range of weights from 575 gm premature infants to 71 kg adolescents. We have encountered a few more complications: a recurrent nerve injury in one premature baby and another in one elective procedure in a 10 kg child. We had one chylothorax, and one patient required transfusion after an open thoracotomy. We have not had any patients with exsanguinating hemorrhage. No deaths have occurred associated with elective procedures. Two premature babies died within a month after operation. We do not believe that these deaths were related to the PDA procedure.

We closely followed our incidence of residual flow, and my first question is whether you have any follow-up echocardiographic evidence that there is not any residual flow or recanalization of flow in your group. Our group

has been followed up to an average of 3 months. No patients have had recanalization, although seven patients do have trace residual flow according to echocardiography. None of these patients have murmurs. We have converted three cases to thoracotomies, none for hemorrhage, and we have reduced hospital stay to a median of 1 day.

In your discussion, you limited your cost analysis to saying that the hospital stay was short. Our interventionists have cooperated with us by calculating the total hospital and physician charges for their last 20 coil occlusions compared with our last 18 VATSI patients. There is no significant difference in cost.

We use a rather different dissection technique. By using four ports, we are able to place a grasping instrument so that we can perform two-handed dissection. We believe that this may help us avoid recurrent nerve injury and allow a more precise dissection of the duct. I am curious to know whether you have considered adding another port to allow two-handed dissection.

Finally, is it your impression, as is ours, that these children are well enough after operation that they could actually be discharged the same afternoon or evening?

Dr. Laborde. Whatever technique is chosen, the important thing is to occlude the ductus. If I insisted on the fact that the dissection must be sufficient and deeply done on each side of the ductus, it is for this.

We had the greatest number of persistent murmurs at the beginning of our experience. Each time we discovered a murmur, we redid the operation immediately. We saw each time that the same thing had happened; that is, the ductus had not been dissected sufficiently.

The same is true concerning the recurrent nerve damage. We had one definite paralysis and five transient paralyzes, and this is probably because at the beginning of the experience we did not take enough care in the distance between the dissection and the instrument, especially the electrocautery. I use the electrocautery because I think it is easier, more rapid and more hemostatic, but perhaps there is another technique. I am sure, however, that if you are at a distance from the nerve, you minimize the risk of injury.

With respect to techniques of PDA closure with thoracotomy, there are not many studies that quantify recurrent nerve paralysis. Some do cite figures this, however, so it does not appear to me that recurrent nerve paralysis is more likely with our method than with others.

Concerning how soon the patients can be discharged after this procedure, we think that 24 hours of hospitalization is a minimum.

Dr. Constantine Mavroudis (Chicago, Ill.). Three years ago, when you presented your initial studies, I expressed concern that exsanguinating hemorrhages could accompany this procedure. To your credit, and that of your entire institution, you have shown us 230 patients not only without any exsanguinating hemorrhages but without any hemorrhages at all, and without death. I ask you one question and continue my message of caution.

Ligation and division of a PDA is typically performed through a muscle-sparing incision by a second-year resident under the supervision of an attending surgeon. The patient is extubated and usually goes home the next day or the day after.

I would like to highlight our experience at Children's Memorial Hospital from 1947 to 1993, which includes the first patients on whom Willis Potts operated. Ligation and division were performed on 1108 patients by a number of surgeons without a death during this period. The residual PDA rate was zero. Your rate of residual PDA is 2.5%, although you addressed that issue concerning the early learning curve and so on. We had a 1.2% rate of laryngeal nerve injury, compared with the 2.4% rate you described. Hospital stay was more or less the same, although I concede that more aggressive management might result in earlier discharge with thoracoscopy than with thoracotomy. The cost issue is somewhat artificial because of cost-shifting techniques and so forth.

In any case, I still worry about this technique being applied to a large population by many surgeons. Obviously, one disaster in 200 or 300 patients does not justify early hospital discharge or thoracoscopic techniques when open thoracotomy could avoid the problem.

I do not intend to make this a criticism, because we should not hold back progress. If this is going to be the new way, then we must learn the process. How easy is this technique to teach others? Also, are you performing all of these procedures? For instance, a PDA closure in any institution is a very easy and very safe procedure, as demonstrated by us and others over a 50-year period. I would like to know how you feel this procedure can be taught and then applied to a large population with minimal complications.

Dr. Laborde. I agree with what you have just said. When I began this experience, my purpose was to succeed in developing this technique for other teams. When you have a technique that works only in your own hands, this does not benefit the patient; perhaps the surgeon, but not the patient. With simple diseases that when approached surgically must have 100% success, if you change the technique or create a new technique, you need to meet two criteria. The first is that the technique must be easy of itself; the second is that you must be able to teach this technique to other people. To perform this technique, you certainly must have some practice in surgery, including some practice in video-assisted surgery. The use of video-assisted surgery has increased, however, and many young surgeons have done other video-assisted operations and thus have experience with this type of surgery. Certainly, this procedure is not difficult.

Some may be concerned because the thorax is closed. What would happen if you injured the ductus or the aorta? When you open the thorax and ligate the duct tissue, however, you can also have problems. When you consider that use of a video-assisted surgical approach is not difficult to teach, you will consider teaching this procedure appropriate for all young surgeons.