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The Preferable Use of Port Access Surgical Technique for Right and Left Atrial Procedures

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ABSTRACT

We analyzed the results of mitral valve operations, either alone or in any combination with the tricuspid valve surgeries in the period from January 2001 till June 2004. The period was divided into two parts, classical sternotomy part (C) (110 patients) and minimally invasive port access part (PA) (105 patients), later being used from December 2002 till now. Also, what we were interested in was the total hospital cost of both types of the procedures and if there are any advantages of port access over the classical sternotomy. The mean age was 61.2 ± 10.2 and 60.3 ± 12.4 (C versus PA) and mean additive Euroscore was 6.5 versus 4.8 (C versus PA). There were statistically significant differences ($P < .0001$) in cardiopulmonary bypass time (CPB) and aortic cross-clamp time (AXT) between both groups: CPB C versus PA: 98.3 ± 33.5 minutes versus 149.2 ± 44.2 minutes (mean ± sd), AXT C versus PA: 62.9 ± 20.6 minutes versus 88.3 ± 26.8 minutes (mean ± sd). There were no statistically significant differences in mortality and stroke for both the groups (mortality $P = 1$, stroke $P = .53$).

There were statistically significant differences in favor of the port access over the classical one for: intensive unit stay ($P = .004$), postoperative stay in days ($P < .0001$), blood transfusion ($P < .0001$), postoperative thoracic bleeding ($P < .0001$), and extubation time in hours ($P < .0001$). Furthermore, costs analyses showed that the average total patient cost was less for port access ($P < .0005$). The differences between endo and classical type suggested that the port access type of surgery is 20% cheaper than the classical one. We may conclude that port access surgery is an acceptable alternative to classical type of surgery, also in complex pathology of the mitral and tricuspid valve.

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INTRODUCTION

Port access was introduced as a technique to perform valvular operations using cardiopulmonary bypass, and combinations of a small right thoracotomy and/or endovascular aortic occlusion in the mid and late 1990s. However, despite their advanced type and level of thinking, many surgical communities around the world were not really very enthusiastic in using this approach; furthermore, at some stage it was almost generally accepted that this technique is far too advanced for the general level of valvular surgery. Despite this, some persisted in developing the technique, and without any doubt it can be said that today, the port access technique has found its place among other new varieties, developed in the last few years (Dogan 2005). It is not just the feeling, but the real data, that it no longer lies somewhere in the corner and more and more surgeons and centers are interested to implement this technique, at least for some of their procedures (Reichenspurner 2005). It is interesting to note that when the surgeons and their teams are mastering the procedure they stay with it and they abandon the classical type of surgery for all the procedures applicable to this technique. However, what still remain unsolved are the comparison and the real meaning of the results of surgery before and after the port access era and the financial impact of port access surgery in those institutions, where it is done on a daily basis. We analyzed the results of mitral valve operations, either alone or in any combination with the tricuspid valve surgeries in the period from January 2001 till June 2004. The period was divided into two parts (Schroeyers 2001, Greco 2002), classical sternotomy part and minimally invasive port access part, later being used from December 2002 till now. Also, what we were interested in was the total hospital cost of both types of the procedures and if there are any advantages of port access over the classical sternotomy.

PATIENTS AND METHODS

The period from January 2001 to June 2004 was divided into two parts: from January 2001 to November 2002-classical part (C) and from December 2002 to June 2004-port access endoscopic part (PA). The gender distribution was 51 males/59 females in classical type and 46 males/59 females for port access.

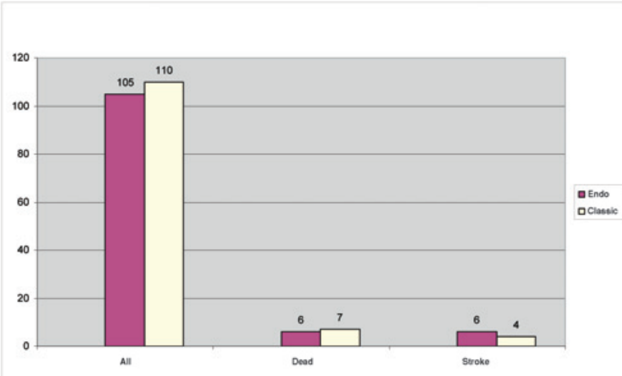

Figure 1. Number of all port access and classical mitral valve operations (together in any combination with tricuspid valve surgery). Port access cases left bars, classical cases right bars. The differences in mortality and stroke rates are not statistically significant (P = 1 for mortality and P = .53 for stroke, student two-paired t-test).

The general characteristics for both groups were 110 versus 105 cases (C versus PA), the mean age was 61.2 ± 10.2 and 60.3 ± 12.4 (C versus PA) and mean additive Euroscore was 6.5 versus 4.8 (C versus PA). The distribution of different operations is presented in Figure 1.

The distribution for the type of operation is shown in Figure 2.

Operating Technique

Operating technique for the classical cases was as follows: complete sternotomy, central arterial cannulation with double venous cannulation, external clamping, and cold blood cardioplegia was delivered antegrade and retrograde in standard fashion. The approach to the left atrium was through either the interatrial septum or direct left atrial incision. The details of classical technique are described elsewhere.

Operating Technique for Port Access

Anesthesia for Port Access. The preparation of the patient starts already at the department with the patients' premedication prior to the transport to the operating theater (OR). After admission to the OR, monitoring devices (ECG, spO2, non-invasive blood pressure measurement) are placed. ECG electrodes are put pre-cordially in such a manner not to occupy the part over the anterior or right lateral side of the thorax, actually, rather at the dorsal side. External defibrillating electrodes are placed in the same way. Two i.v. cannula G14-16 are inserted into the peripheral veins. Arterial catheters are inserted into the left and right radial artery to measure arterial blood pressure directly.

The general anesthesia is induced using the standard medication. The double-lumen endobronchial tube (Carlens or Portex) is used to enable single lung ventilation during the operation. The transesophageal echo (TEE) probe is inserted by passing through the endobronchial tube and acquiring the position to expose the right atrium well. The four-lumen central venous catheter is inserted through the left internal jugular vein, which is needed to measure the central venous pressure, and for delivering of vasoactive drugs. The position of the tip is checked by the TEE. The pulmonary artery catheter is inserted also through the left internal jugular vein when needed.

Transesophageal echo screening is performed to inspect valves and to confirm, or in addition to pre-op patient screening to check, if there is excessive atherosclerosis of the aorta, to check if the aortic valve is competent (if not competent, antegrade cardioplegia cannot be delivered sufficiently via endoclamp catheter), and to measure aortic diameter (if above 4 cm endoclamp catheter should not be used). Transcutaneous echo may be used to determine the position and status of the femoral vessels.

The 17-Fr venous cannula is inserted through the right internal jugular vein using Seldinger technique, having administered 5000 IE of Heparin. The guide wire is inserted always on the right side of the neck, in the level of thyroid cartilage, and not lower to it (Figure 3), to prevent tearing of the subclavian vein or junction between jugular and subclavian vein due to stiff dilator use.

The position of the guide wire and later the position of the cannula are carefully monitored by the TEE until they

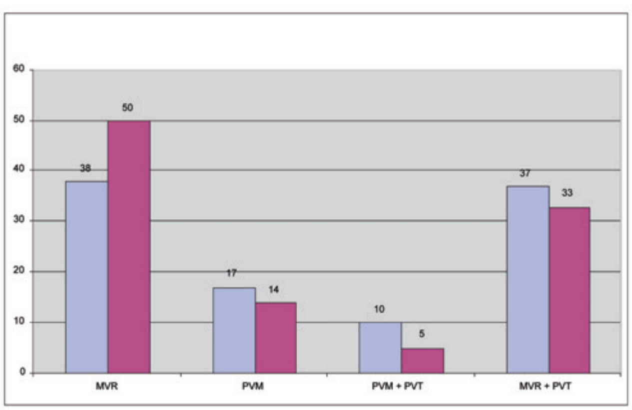

Figure 2. Number of mitral valve replacements (MVR), mitral valve repairs (PVM), and combined cases (with tricuspid valve repair-PVT) for port access technique (right bars-red) and classic technique (left bars-blue).

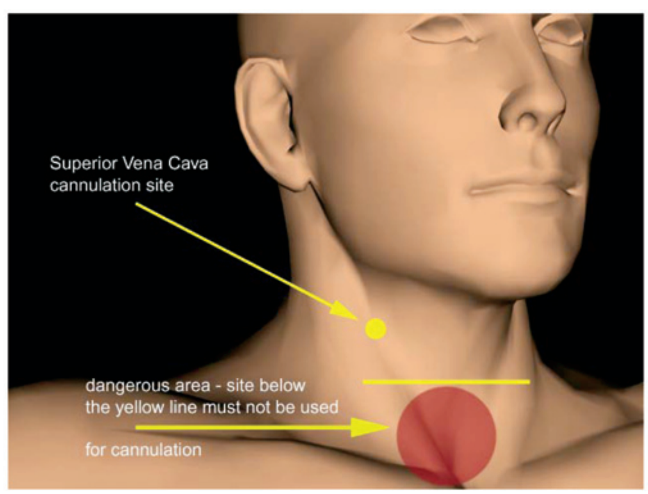

Figure 3. Cannulation site for superior vena cava.

reach the final position at the junction of superior vena cava and the right atrium as seen as the very tip at the cranial pole of right atrium by the TEE. The Foley urinary catheter is inserted and connected to the temperature probe to measure temperature. The temperature is also measured in the pharynx. The oxygen saturation is monitored continuously by the fingertip pletismography and repetitive blood gas analyses. The anesthesiologist performs all the procedures up to now while the patient is lying on the table in the standard supine position. Meanwhile, the scrub nurse prepares the instruments and the video presterilized cables for the operation. Special attention is paid on the flushing and rechecking of the endoclamp aortic balloon catheter. The balloon is inflated and deaired carefully. Additionally, the tubing for the upper venous cannula is prepared and primed with the solution. Afterwards, the surgeon-assistant sets the camera holder to the right of the patient so that the vertical arm position coincides with the very tip of the patients' head (Figure 4). Accordingly, the patient is mostly moved some centimeters down along the table to acquire the desired position with respect to the camera. Finally, the patient is further inclined to the left, the right hemithorax is lifted up by some 15-20 degrees with respect to the table axis (Figure 4). We make sure the right arm is retroflexed in the shoulder maximally in order to expose the right lateral hemithorax better.

Then, the skin incision sites are occasionally marked, especially in women the infra-mammary groove is determined, the operative sites are prepped and draped. The tubing for the upper venous cannula is put between the first and the second layer. The cautery cable, the cell saver, and the camera video cables are set in place and are connected. The rest of the cardiopulmonary bypass (CPB) tubing is delivered at the table and clamped one/one, and the vent line is interrupted to insert the return valve, directed toward the pump. Atrium retractor holder is fixed to the left side of the table at the level of the submammary groove or pectoralis muscle border, respectively.

Advancing further, femoral incision is made first to prepare for the CPB.

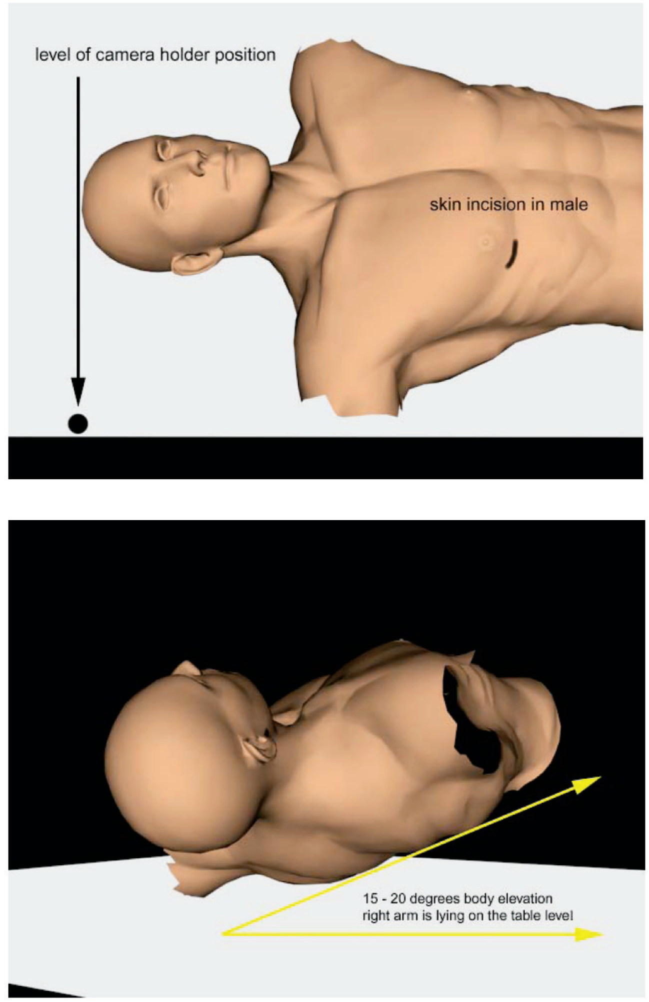

Figure 4. Postitioning of the patients in the operating room.

Surgical Technique for Port Access

Incisions. First, a 1.5 cm long skin incision is made by the scalpel, directly over the right femoral artery and vein in such a fashion that outer 1/3 of the artery and vein is not affected. The height of incision is around 1 cm below to the inguinal ligament with direction exactly in the line of femoral groove. Next, the subcutaneous tissue is dissected with electrocautery and 1.5 cm sharp retractor is made to expose the still covered artery and vein. The small hook, pulling skin lateral is used to help position common femoral artery in the mid-part of incision. With scissors the upper part of femoral artery of just 1 cm in length is exposed to the level of adventitia. It has to be mentioned that not any other dissection exposes the artery, leaving it surrounded with all adjacent subcutaneous structures. Afterwards, the hook pulls medially, positioning the femoral vein in the mid-part of skin incision, and the upper part of the vein is exposed in the same manner as with the artery. When this is done, two 5/0 Prolene purse string sutures with tourniquet applied to them are positioned on a femoral vein. First one uses four bites and the second one just three. Then two 5/0 Goretex sutures with Ethicon pledgets and tourniquets are used to prepare the femoral artery for the cannulation (Figure 5).

Second, the thoracic skin incision is made. There are differences in men and women. In men the incision in parallel to the nearest intercostal line lying below the nipple, with skin incision in principle laterally to midclavicular line.

In women, the marker is used prior to cleaning to mark the submammary groove, which is distorted when the patient is positioned for surgery. So the skin incision follows this line and is typically done also slightly more laterally to the midclavicular line than in men. The length of skin incision in thorax is 2.5-3 cm done with scalpel and then subcutaneous structures are dissected with electrocautery but not yet exposing intercostal musculature. The intercostal space where the real approach will be is chosen under the following criteria:

1. Convenience for the patient: some patients may be obese and in those it may be difficult to expose the 4th inter-

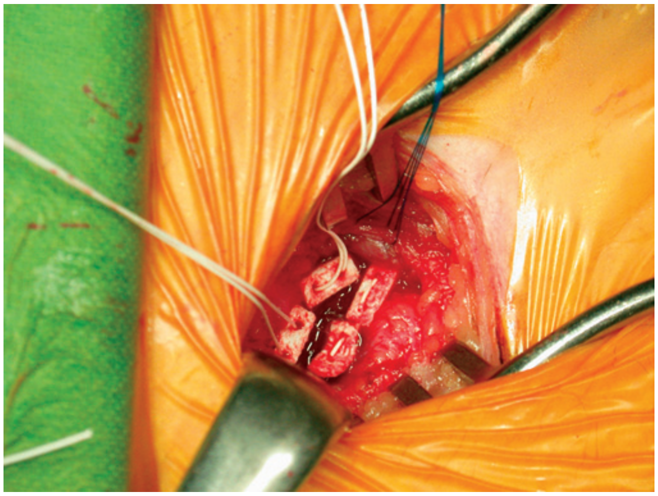

Figure 5. Right femoral incision is 1.5 cm long.

costal space with this limited incision, leaving more post-operative pain, tissue destruction and damage, so the 5th space is used.

2. Shape of the thorax: if the thorax is more wide, the heart is lying more on the diaphragm, so 5th space can be used. If the thorax is narrow, and the heart is positioned more vertically, the 4th intercostal space will be a good choice. The chest x-ray is carefully examined prior to surgery and all the intercostal spaces from 4th to 6th are considered for approach.

3. Position of the diaphragm: sometimes the diaphragm is positioned very high, so higher intercostal space than normal may be more convenient to use.

When it is determined which intercostal space will be used the electrocautery is used to dissect the tissues deeper, not enlarging the length of incision, but deepening it and special care is taken that all the bleeding is prevented. At least at this time the lungs on the right side should be deflated. When the pleural space is opened, the length of the intercostal incision is exactly of the same size as the size of the skin incision. Immediately after the pleural space opening the 3 mm skin incision is made, one intercostal space lower and 2-3 cm more laterally, the 5 mm wide port is introduced, palpating and protecting the diaphragm with left-hand middle finger. This port will be used for venting and at the end for drainage, however, at this stage 2 mm wide tube with CO_2 connection is inserted through this port immediately-the CO_2 flow is 3 liters/minute. Around 30 cm of the tube is inserted into the thorax, trying to reach the lowest part of it with the opened end part of the tube. Then, as a rule, in the same intercostal space as the intercostal incision was done another 5 mm port is inserted, which will be used as a camera port. In some rare cases this can be done also one intercostal space higher. Medium size soft tissue retractor is inserted through the intercostal incision and soft tissues are pulled aside to open the working port (Figure 6).

Cannulation

In general, no touch technique is used for artery and vein. First, the vein cannulation is done after full heparinization. The anesthesiologist shows TEE view of right atrium with superior (SVC) and inferior vena cava (IVC). A needle is inserted with the opening looking up into the femoral vein, guiding wire is inserted and shown in the right atrium. Then hard 14Fr dilator is used to dilate the vein, prior to insertion of venous cannula. Insertion of the venous cannula is in five stages: first 10 cm of smallest dilator is inserted, next 5 cm of the middle and then the cannula till the holes are inside the vein. At all the time guiding wire is observed on TEE. As soon as holes are inside, the two dilators are removed for 5 cm and the cannula is pushed into the right atrium. There should be no resistance at any time during advancing cannula. At the 35 cm mark the two dilators are pulled out for about 10 cm and the tip of venous cannula is positioned at the junction of IVC and right atrium.

The both cannulas (from SVC and IVC) are connected and loosely secured, thus enabling reposition during operation if necessary.

Next, arterial cannulation is performed under the same rules as venous. Thoracic aorta is shown on TEE, guiding wire is inserted through the femoral artery and pushed inside till the wire is clearly seen on TEE. The artery is dilated with 14Fr hard dilator and then Port Access endoreturn arterial cannula is inserted 2-3 cm into the femoral artery, connected, deaired, and tightly secured with 2/0 suture. The perfusionist gives 100 mL of fluid slowly through this cannula, perfusion pressure is monitored, and TEE is checked. During this procedure, the endoaortic balloon (endoclamp) is inserted into the Y connector. When the perfusion test is stopped, the guide wire for the endoclamp is inserted into thoracic aorta, the wire has to be seen on TEE. Then anesthesiologist shows aortic valve and ascending aorta on TEE while the guiding wire is advanced almost to its end into the endoclamp. At this stage the wire is rarely seen on TEE in ascending aorta,

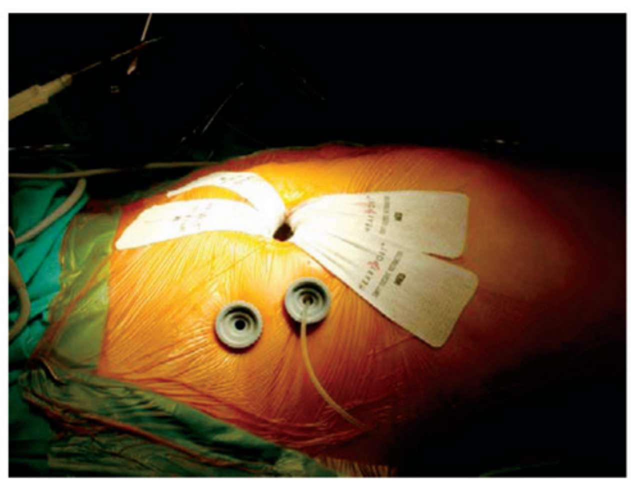

Figure 6. 2.5-3 cm long working port and two 5 mm ports: left one for the camera and right one for left atrial vent.

because of its length, so the endoclamp is inserted into the femoral artery and up into thoracic aorta. As soon as guide wire is seen on TEE in ascending aorta, the assistant pulls it backwards while the surgeon pushes the endoclamp into the aorta. Under this circumstance, the endoclamp is slowly advanced into ascending aorta. When it is seen on TEE in ascending aorta, the guiding wire is removed completely, and the endoclamp is withdrawn till it almost disappears on TEE. Just a small part of distal tip has to be seen on TEE. The endoclamp is then secured just with the help of a locking device on Y arm of arterial cannula. It has to be explicitly mentioned again that firstly the guiding wire and then later on endoclamp have to be seen on TEE in ascending aorta. If the guide wire is not seen in ascending aorta while its whole length is in the patient and also the endoaortic balloon is reasonably advanced into thoracic aorta, every measure has to be taken to see and position it in ascending aorta to prevent positioning in any of great aortic arch arteries.

Operation

The 5 mm camera is inserted through the camera port. The pleural cavity should now be with completely deflated right lungs, so the 2 mm needle with sheet is inserted 2 cm dorsal to camera port, needle withdrawn and CO_2 tube inserted through this port.

If diaphragm is high, making exposure difficult or making operating angle steep, 2/0 figure of eight suture is placed on muscular part, a needle as much as close to the diaphragmatic level is inserted dorsal to vent port, suture snare applied pulling diaphragmatic suture outside of thoracic cavity, tourniquet applied and diaphragm pulled caudally.

Pericardial fat is removed with electrocautery if necessary in those areas, where the pericardial opening will be. Special attention is paid to the area near the phrenic nerve, cranially and caudally to it.

Then the cardiopulmonary bypass is started, and slowly, if necessary, vacuum-assisted drainage is used. The pericardium is opened for 1 cm, two 2/0 stay sutures on both sides are pulled up and the rest is opened in inverted T fashion. Caudal part of cut is ending directly above the IVC, cranial part is ending at the pericardial eversion near SVC. Two 2/0 stay sutures in U fashion are applied horizontally along the phrenic nerve, above or if suitable, below it. A needle is inserted between camera port and CO_2 port, suture snare is used to pull both "phrenic nerve stay sutures" outside the thorax, tourniquet applied for securing both sutures.

Soft dissection with tip of cell saver aspirator is used to determine the position of IVC in relation to the right and left atrium. If possible, tip is inserted below IVC, reaching diaphragm, so the left atrial opening later on will not interfere with the right atrium.

Sharp dissection with scissors is used to separate left and right atrium horizontally in interatrial groove.

Endoaortic Crossclamping. Distal part of the tip of the endoclamp is determined on TEE. The perfusionist vents the aortic root line for a few seconds. Assistant surgeon is slowly inflates the balloon, while the surgeon pulls the endoclamp out of the ascending aorta. As soon as 1/3 to 1/2 of the determined (related to aortic diameter) balloon volume is given, the scrub nurse is as fast as possible injecting adenosine (.25 mg/kg) via a side port of endoclamp catheter. At this time heart is stopped immediately and the surgeon pulls some additional millimeters of the endoclamp from the aortic valve into the place above sinotubular junction (Figure 7). This will also take the slack out of the catheter. As soon as adenosine is stopped, the perfusionist starts to give the cardioplegia. The pressures (right and left radial, aortic root, cardioplegia pressures, and pressure in the balloon) are carefully observed; if necessary some small adjustments in the endoclamp position are done. Then the catheter is locked and the insertion depth of the catheter is noted. When the team agrees that the situation is stable, and the heart is adequately stopped, the .7-1 cm small incision in the left atrium is made close to the interatrial groove. Immediately, the cardiotomy aspirator decompresses the heart.

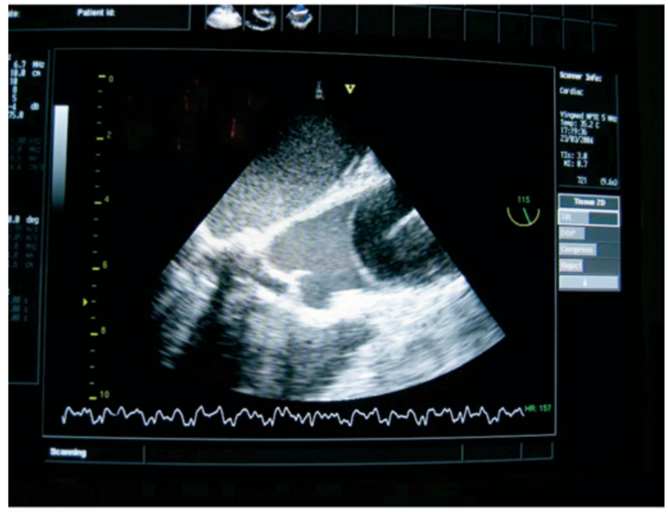

Figure 7. Endoaortic balloon inflated and placed in the region of sinotubular junction between aortic valve and innominate artery.

Straight port access scissors are used to open the remaining of the left atrium, in most cases approximately 3.5-4 cm. Care is taken not to open the left atrium too much but exactly in accordance to the wideness of left atrium retractor which the surgeon will use.

If the left atrium is small, wider and shorter left atrial retractor is used (3.5 cm width).

In enlarged left atria TEE evaluation prior to cardiac arrest is used to determine the position of the enlargement (the atrium could be enlarged in many different directions). According to this longer or shorter left atrial retractors are used in combination with their wideness.

During decision making left atrial vent is pushed through the 5 mm vent port into the left superior or inferior pulmonary vein. This vent has a smooth tip, air lock screw and is preformed in L shape. Since this is still the time, when cardioplegia is given it is important to use left vent and cardiotomy aspirator in combination.

The left atrial retractor is put through the thorax into the left atrium and camera is pushed into position to show the mitral valve. The left atrial retractor is temporarily positioned in such a way, that it is not interfering with lateral (in this case left side as seen on screen) part of the atrium-this is the area where the inflated endoaortic balloon is-the interference may cause balloon migration due to applied force, challenging and complicating operation resulting in poor exposure of the anterolateral mitral commissural region.

At this stage the position for left atrial rectactor holder arm is determined, and through 3 mm hole the retractor arm is inserted into the thorax. It has to be present in mind that this insertion may interfere with internal mammary artery, still not adequately exposed pericardium or sometimes even with soft tissue retractor. Having this in mind the surgeon is advised to prepare the necessary and optimal conditions during the whole course of operation from the very start.

Then left atrial retractor is positioned. The depth should not to be great, the mitral annulus below the retractor arm has to be seen clearly at this stage. Also the retractor arm should be slightly rotated counter-clockwise for about 10-20 degrees and pulled directly up till such an extent that anterior leaflet falls down completely unobstructed.

Then the mitral valve is repaired or replaced.

When 2/3 of the sutures are tied down, the perfusionist starts to heat the patient. When the sutures are cut, the atrial retractor is moved vertically down till the left atrial suture line is slightly approximated. First, figure of eight suture is put in the upper (near SVC) corner and then the left atrial retractor is removed. After few stitches the lower corner (near IVC) is approached and sutured till both the sutures meet. Then the anesthesiologist inflates the left part of the lungs and the perfusionist fills the heart, while the surgeon is maintaining the left atrial suture line open for "deairing". The suture is tightened down, heart emptied again and left lungs deflated. The left atrial suture line is checked while heart empty and then again with full (but still arrested) heart. If necessary, now is the time for additional sutures. CO_2 bathing is stopped.

Temporary pacemaker wire is placed in the musculature of the right ventricle, and if there is no place (fat) on the left ventricle.

At this stage the perfusionist fills the heart, the anesthesiologist ventilates the left lungs and when on TEE the left atrium is visualized and the endoaortic balloon is emptied for about 2/3 of the filling volume (1/3 still remaining) and aortic vent is opened to remove air if present still there.

The left atrial suture line is checked while the heart is beating and if everything is acceptable, the suturing of the pericardium is done with 3/0 Prolene, leaving about 1 cm^2 open for drainage.

The thorax is aspirated for blood and when both lungs are filled with air, perfusionist lowers the perfusion and finally stops it.

Protamine is given and during this stage firstly femoral venous cannulation is discontinued in retrograde manner, meaning inserting the nonperforated dilator into the cannula, preventing the loss of blood from the holes.

During this, the ports are removed, thoracic drain is inserted through the vent port, soft tissue retractor is removed, and all the port holes are sutured.

After withdrawing the balloon catheter from Y arm, femoral decannulation is also retrograde; inserting the nonperforated dilator into the femoral cannula removing it while simultaneously the Goretex sutures are tightened down.

Normally, no additional hemostatic sutures are needed on both cannulation sites.

When thoracic musculature is sutured (no rib sutures are used because the opening is so small and so preventing postoperative pain from rib involvement) the epidural catheter is inserted from left side of the patient, through the retractor arm opening, between the internal and external respiratory muscles.

The catheter is secured and connected with patient's control analgesic pump (PCA) used to deliver local anesthetic at the end of the operation and next three days.

The remaining wounds are sutured intradermally with 5/0 Vicryl.

The SVC is decannulated, the puncture site pressed down for a few minutes with the patient in antitrendelenburg position. The thoracic drain is connected with negative pressure suction line, the patient extubated on table and transferred in ICU.

RESULTS

What is to be expected in port access surgery is the marked increase in cardiopulmonary bypass time and corresponding aortic cross-clamp time. In our series we have used from the 10th case on the so-called "pure port access surgery," meaning the skin incision was 2.5 to 3 cm, there was no rib retraction with just soft tissue retractor use. With such a technique it is mandatory to work almost 90% of the time on camera (on monitor), and 100% of time during mitral valve procedure.

The comparison between port access and classic techniques for cardiopulmonary bypass time and aortic cross-clamp time is shown in the Table.

The intensive care unit stay in hours was much shorter for PA cases, as well as postoperative stay in days, less blood transfusion was used in PA cases, thoracic bleeding was smaller for PA cases and extubation time much shorter (Figures 8 to 12).

Comparison of Average Total Patient Cost

For all the cases we asked the financial department to give us the report of total hospital cost of each individual procedure (THCP) (Figure 13). Because it is very difficult to compare the costs in different environments, we normalized

Mean Values ± Standard Deviation of Cardiopulmonary Bypass Time (CPB) and Aortic Cross-Clamp Time (AXT) for Classic and Port Access Type of Surgery*

	Classical (mean ± sd)	Port Access (mean ± sd)
CPB time, min	98.3 ± 33.5*	149.2 ± 44.2*
AXT time, min	62.9 ± 20.6*	88.3 ± 26.8*

*$P < .0001$.

them, making them comparable with other institutions, not necessarily operating in the same country. Because the reimbursement amount is a known parameter for each procedure we defined the THCP as a unit, dependent on the reimbursement amount (Figure 14), meaning the normalized numbers above 1 shows that the hospital is actually spending on the average less money per procedure than it is given from the reimbursement, in other words, procedures, having THPC numbers above 1 are generating "extra" money for the hospital, and the procedures with THPC numbers below 1 are net to consumers of the hospital budget.

DISCUSSION

We can classify the port access or key hole surgery with special emphasis to the mitral valve surgery according to the type of aortic clamping, cardioplegia delivery, and retractor use.

Either external or internal clamping can be used and both techniques have their positive and negative sides, different levels of technical difficulties, wide variety of adverse effects to the patients, and also not trivial effects according to the comfort of the surgeon, where the comfort is meant as a state of mind, showing directness, sincerity, and self-confidence.

External occluding clamps, like the Chitwood clamp, are easy to apply; their use and actions are easily reproducible and no special training is needed. However, all of them have the so-called scissor effect on the clamped vessel (Gersak 1996), which is expressed more and more if the vessel is calcified.

By measuring the actual force, used for vessel occlusion, we can actually see this effect, shown here at the end of the clamping, where the occlusion force is practically 10 times bigger than needed, resulting in intimal breaking and possible sites for thrombotic formations, or although rare, dissections.

Therefore, there is no wonder that the embolic events, counted in the middle cerebral artery with TCD are present during clamping and declamping. There are no differences in the total number of embolic events either in classical or port access endoaortic balloon type of surgery, however, there are differences in the timing as shown elsewhere.

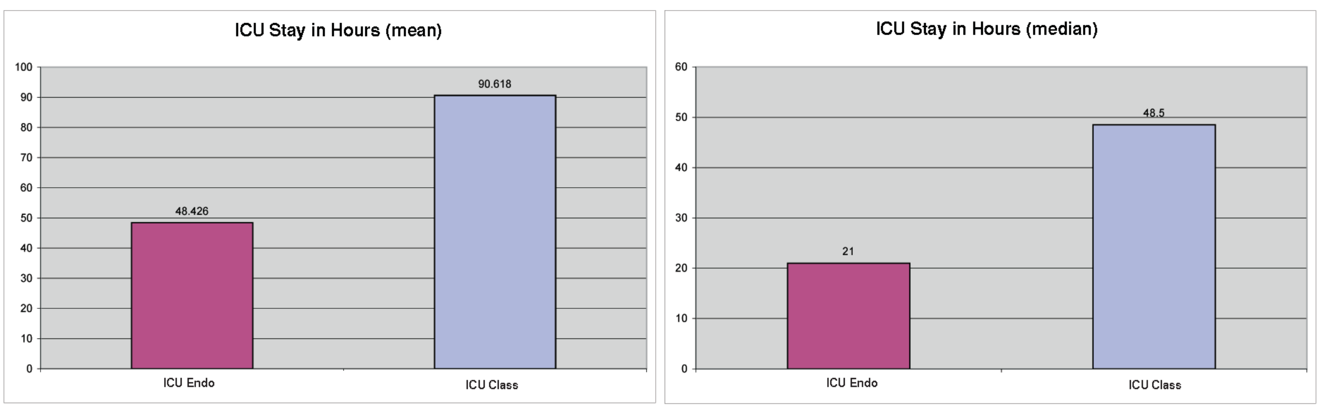

Figure 8. Intensive care unit stay in hours (mean - P = .004 and median) for port access and classical cases.

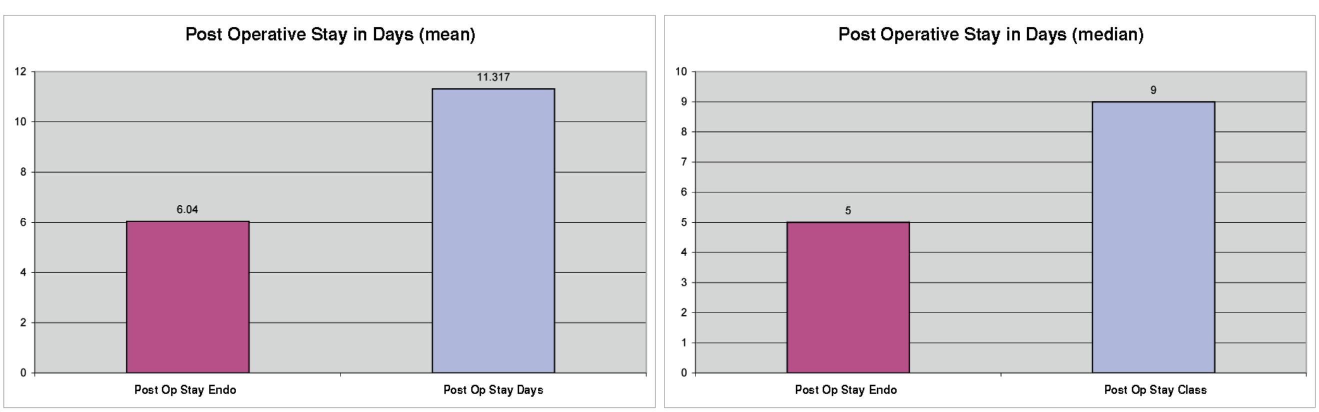

Figure 9. Postoperative stay in days (mean - P < .0001 and median) for port access and classical cases.

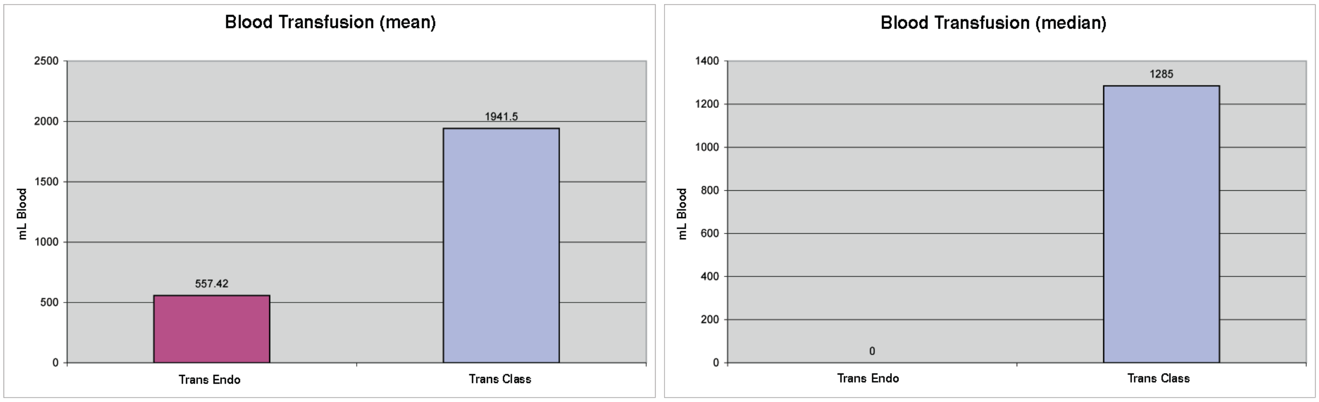

Figure 10. Blood transfusion in milliliters (mean - $P < .0001$ and median) for port access and classical cases.

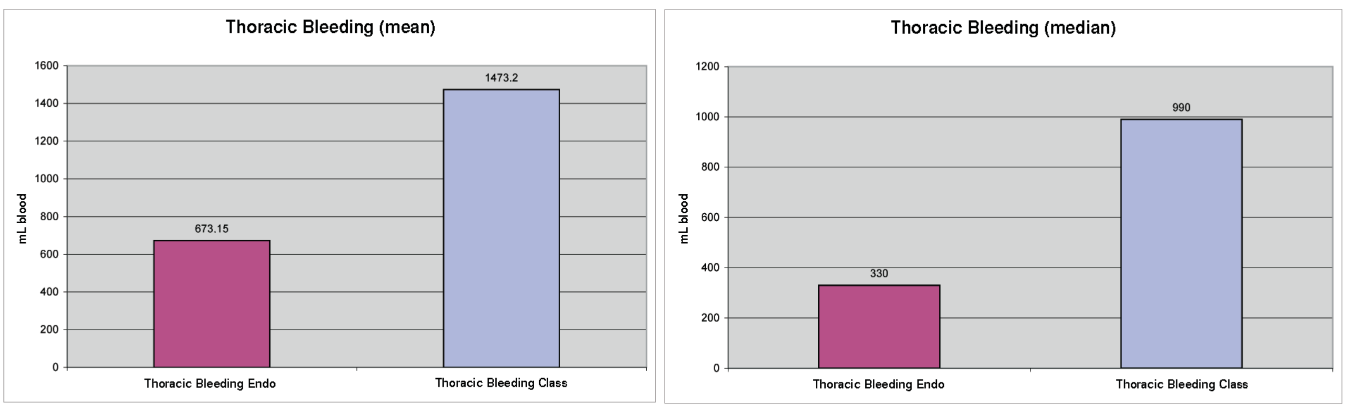

Figure 11. Postoperative thoracic bleeding (mean - $P < .0001$ and median) for port access and classical cases.

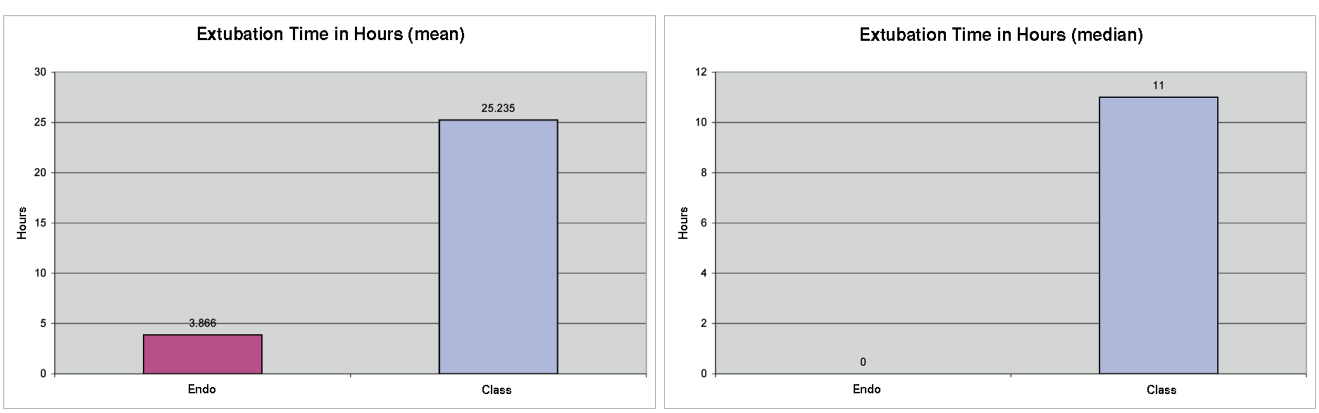

Figure 12. Extubation time in hours (mean - $P < .0004$ and median) for port access and classical cases.

Figure 13. Average total patient cost for port access and classical type of surgery ($P < .0005$).

The external clamp elsewhere generates more embolic events at the start of the procedure, perhaps due to aortic manipulation and during all the time prior to clamp removal, while the endoaortic clamping is supposed to produce more events at the moment of clamp removal. We have to know, that microembolic events are counted, but not classified per se, meaning that we have to define what is the type of embolic dissemination and try to find a way to minimize it, regardless of the clamping technique used.

Another method used, at this time in small number of centers, is the so-called portaclamping, almost parallel clamping technique with graduated, manually determined external vessel pressure. Here the guide wire is inserted through a separate port, both clamp arms are inserted resembling the principle of Seldinger technique, and then the aorta is clamped. However, the additional port of 12 mm is needed for insertion, the pressure of the clamp arms is not measured directly and cardioplegia at this stage of portaclamp evolution has to be done antegrade with a needle application into the aortic root. This all means bigger skin incision, use of small retractors, and possible difficulties in suturing the cardioplegia needle insertion under high aortic pressure.

The endoaortic balloon principle is aortic occlusion with integrated antegrade cardioplegia delivery from the inner side, this minimizing the "wall crush" and microscopic intimal tears of the external clamping. However, the level of comfort of the surgeon is not as easy to establish and reach as in other clamping techniques, and some additional learning is mandatory.

We have used the endoaortic balloon clamping in all of our cases without any problems. However, we strongly believe that expanded monitoring is needed to be able to control all the parameters. This means right and left radial pressure, intra-aortic balloon pressure, and aortic root pressure and cardioplegia delivery pressure monitoring.

It is without any doubt that the CBP time in PA cases is significantly longer than in C cases. This is expected, not just because of the learning period, but also for some other reasons, such as a need for right lung deflation and possible problems with arterial saturation, in some cases it is safer to dissect the heart and great veins during CPB, especially in redo cases. Despite that fact we see that our CPB times and AXT times are comparable with others, which are dividing the PA surgery into learning, advanced and overall stage.

Comparing the CPB and AXT time for different pathologies we can see that the AXT time is in the same range for mitral valve replacement, and any combination of mitral valve and tricuspid valve surgery. The longest AXT time is to be expected in mitral valve repairs alone (Figure 15). We think this is due to possible complex reconstructions, which are to be expected if we decide to repair the valve. However, we also believe that the mean time of 104 minutes for mitral valve repair is acceptable, since also in classical type of surgery the AXT above 2 hours are not an exception. What is important that the repair is good and the valve will be fixed for life, and that the cardioplegia and cardiac protection is effective and working.

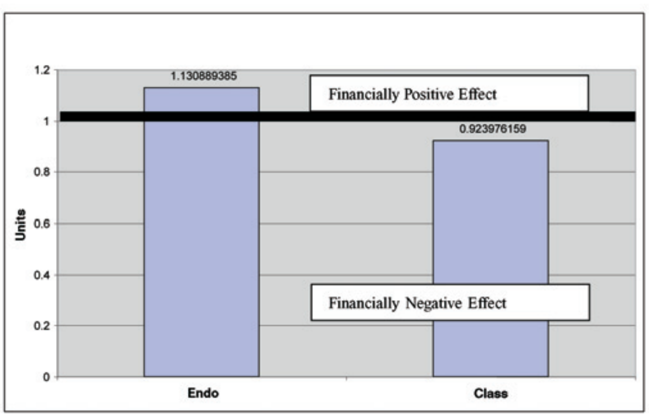

Figure 14. Total hospital cost of the procedure, normalized according to reimbursement amount. Values above the black line (above 1) mean there is financially net positive effect on hospital budget, values below show netto loss for the hospital. The difference between endo and classical types in this case is .2069, meaning on average that the port access type of surgery is 20% cheaper than the classical one.

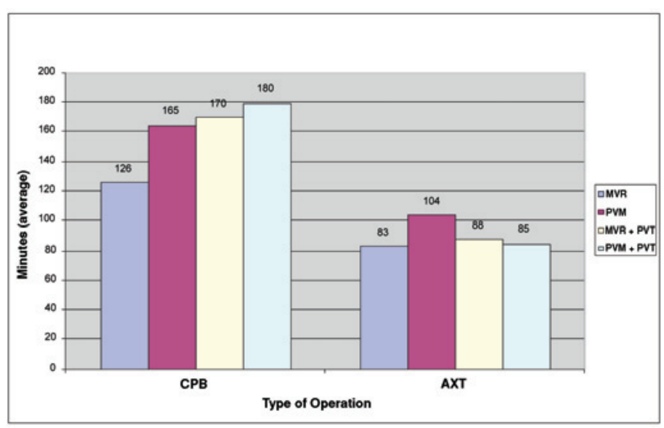

Figure 15. Aortic cross-clamp time (AXT) and cardiopulmonary bypass time (CPB) for different mitral and tricuspid valve port access operations.

The reason that the CBP times for combined mitral and tricuspid valve cases (Kypson 2002, Tripp 2002) are longer, but the AXT is in the same range, is that we are repairing the tricuspid valve on the beating heart, thus lowering the AXT time. It is understandable that this goes on the length of CPB time, because the tricuspid valve repair on the beating heart during PA surgery is a little more demanding than on the arrested heart.

The mean stay in intensive care unit between PA and C cases is on the average 2 days for PA cases and 4 days for C cases. What is important is the median stay, meaning the PA cases are to be expected to stay in intensive care unit for 1 day (21 hours)-practically overnight.

Also the postoperative stay in days is significantly shorter for PA cases. The rehabilitation is much faster and the physiotherapy is more "aggressive" because there is no fear that sternotomy is going to break. The median stay after the surgery to be expected is in general 5 days.

The so-called "pure" PA surgery means that there are just a few cuts on the patients body-2.5 to 3 cm incision on the right thorax, corresponding pericardial and left atrial cut, 1.5 cm right groin incision and some small 2 to 5 mm holes for ports and holders. If during the dissection care is taken, and if the hemostasis at the end is as perfect as possible it is to be expected that the postoperative bleeding will be minimal. This is valid also for the blood transfusions, showing that in PA cases the median volume transfusion was 0.

We had to reopen three cases because of the bleeding, the cause was in all the cases the pericardial fat.

Almost 80% of our cases were extubated on table, and the mean time from the skin suture to extubation was in those cases 11 minutes. All the other cases were extubated on the average less than 4 hours after the skin suture.

Comparing the THCP between PA and C cases we see that the above-mentioned factors, which are PA related, are contributing to lower the costs of the whole treatment in PA cases. These are the reduced length of stay in intensive care unit, less amount of blood transfusions and any blood derivatives, faster rehabilitation and reduced length of overall stay.

Of course there are specific complications, which are typical for PA surgery, the most important perhaps, at least in our series the need for additional pleural punctions, generally weeks after the discharge. We think that this is due to pleural irritations, generally producing the liquid into the right thoracic chest.

In our series we had two aortic dissections, both started from the femoral vessels. Opening of the ascending aorta during repair showed completely intact intimal layers at the site of aortic endoclamping. We are convinced that it is not the endoclamp which was responsible.

It is therefore mandatory to use an extremely conservative approach to the femoral artery cannulation. The variations of the iliac vessels and the asymmetry of the aortoiliac anatomy have to be taken into account. In tortuous types we have to stop. It is wise to instruct our cardiologists that while doing the cardiac catheterization, they should think on the possibility for endo surgery and show us the iliac vessel anatomy.

What is extremely important is to determine the patients with atheromatous plaques in descending aorta, which is a contraindication for PA surgery.

It has to be emphasized that to reach a certain level of comfort in PA surgery (Hellgren 2002), it is necessary to invest some time in training and learning and that the whole surgical team has to work as a group. Even if a little longer skin and thoracic incisions are made and a reasonable level of rib retraction is used, the patients are still benefiting a lot from this type of surgery.

At the end we may conclude that port access surgery is an acceptable alternative to classical type of surgery, also in complex pathology of the mitral and tricuspid valve.

The smaller incisions are having better cosmetic effect, they produce less pain and the bleeding rate is minimal. The port access patients return to their homes and work faster, and all that contributes to lower the cost of their treatment.

REFERENCES

Dogan S, Aybek T, Risteski PS, et al. 2005. Minimally invasive port access versus conventional mitral valve surgery: prospective randomized study. Ann Thorac Surg 79:492- 8.

Gersak B, Trobec R, Krisch I, Psenicnik M. 1996. Loss of endothelium-mediated vascular relaxation as a response to various clamping pressures. Eur J Cardio-thorac Surg 10:684-9.

Greco E, Barriuso C, Castro MA, et al. 2002. Port-Access™ cardiac surgery: from a learning process to the standard. Heart Surg Forum 5(2):145-9.

Hellgren L, Kvidal P, Stahle E. 2002. Improved early results after heart valve surgery over the last decade. Eur J Cardio-thorac Surg 22:904-11.

Kypson AP, Glower DD. 2002. Minimally invasive tricuspid operation using port access. Ann Thorac Surg 74:43-5.

Reichenspurner H, Detter C, Deuse T, et al. 2005. Video and robotic-assisted minimally invasive mitral valve surgery: a comparison of the port-access and transthoracic clamp techniques. Ann Thorac Surg 79:485-91.

Schroeyers P, Wellens F, De Geest R, et al. 2001. Minimally invasive video-assisted mitral valve surgery: our lessons after a 4-year experience. Ann Thorac Surg 72:S1050-4.

Tripp HF, Glower DD, Lowe JE, Wolfe WG. 2002. Comparison of port access to sternotomy in tricuspid or mitral/tricuspid operations. Heart Surg Forum 5(2):136-40.