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Original Article

Evolution of strategies for management of the patent arterial duct

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Abstract Persistent patency of the arterial duct represents one of the most common lesions in the field of congenital cardiac disease. The strategies for management continue to evolve. In this review, we focus on management beyond the neonatal period. We review the temporal evolution of strategies for management, illustrate the currently available the techniques for permanent closure of the patent arterial duct, review the expected outcomes after closure, discuss the current controversy over the appropriate treatment of the so-called "silent" duct, and provide recommendations for the current state of management of patients with persistent patency of the arterial duct outside of the neonatal period.

At the Congenital Heart Institute of Florida, we now recommend closure of all patent arterial ducts, regardless of their size. Before selecting and performing the type of procedure, we explain the natural history of the persistently patent arterial duct to the parents or legal guardian of the child. Particular emphasis is placed on the risks of endocarditis, including the recognition that many cases of endocarditis may not be preventable.

The devastating effects of endocarditis, coupled with the perception of more anecdotal reports of endocarditis with the silent duct, as well as the low risk of interventions, has led us to recommend closure of the patent arterial duct in these situations. We now recommend intervention, after informed consent, for all patients with a patent arterial duct regardless of size, including those in which the patent duct is "silent". We recognize, however, that this remains a controversial topic, especially given the new recommendations for endocarditis prophylaxis from American Heart Association.

Since 2003, our strategy for closure of the patent arterial duct has changed subsequent to the availability of the Amplatzer occluder. This new device has allowed significantly larger patent arterial ducts to be closed with interventional catheterization procedures that in the past would have been closed at surgery. During the interval between 2002 and 2006 inclusive, the overall surgical volume at our Institute has been stable. Over this period, the number of patients undergoing surgical ligation of the patent arterial duct has decreased, with this decline in volume most notable for the subgroup of patients weighing more than five kilograms. This decrease has been especially notable in thoracoscopic procedures and is attributable to the increased ability to close larger ducts using the Amplatzer occluder.

For infants with symptomatic pulmonary overcirculation weighing less than 5 kilograms, our preference is for the surgical approach. For patients who have ductal calcification, significant pleural scarring, or "window-like" arterial ducts, video-assisted ligation is not an option and open surgical techniques are used. When video-assisted ligation is possible, the approach is based on family and surgeon preference. When open thoracotomy is selected, we usually use a muscle-sparing left posterolateral thoracotomy.

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For patients weighing more than 5 kilograms, we currently recommend percutaneous closure for all patent arterial ducts as the first intervention, reserving surgical treatment for those cases that are not amenable to the percutaneous approach. For symptomatic infants weighing greater than 5 kilogram with large ducts, we prefer to use the Amplatzer occluder. In rare instances, the size of the required ductal occluder is so large that either encroachment into the aorta or pulmonary arteries is noted, and the device is removed. The child is then referred for surgical closure. We can now often predict via echocardiography that a duct is too large for transcatheter closure, even with the Amplatzer occluder, and refer these patients directly to surgery.

For patients with an asymptomatic patent arterial duct, we prefer to wait until the weight is from 10 to 12 kilograms, or they are closer to 2 years of age. If the patent arterial duct is greater than 2.0 to 2.5 millimetres in diameter, our preference is to use the Amplatzer occluder. For smaller ducts, we typically use stainless steel coils. Using this strategy, we close all patent arterial ducts, regardless of their size.

Keywords: Ductus arteriosus; minimally invasive surgery; video-assisted thoracoscopic surgery

Persistent patency of the arterial duct represents one of the most common lesions in the field of congenital cardiac disease. The strategies for management continue to evolve. In this review, we will focus on management beyond the neonatal period, with the following objectives:

- Review the temporal evolution of strategies for management.
- Illustrate the currently available the techniques for permanent closure of the patent arterial duct.
- Review the expected outcomes after closure.
- Discuss the current controversy over the appropriate treatment of the so-called "silent" duct.
- Provide recommendations for the current state of management of patients with persistent patency of the arterial duct outside of the neonatal period.

History

It is likely that Galen first described the persistently patent arterial duct, even before the name of Leonardo Botallo became associated with this lesion during the Middle Ages.[1,2] Until the advent of Doppler echocardiography, the diagnosis was secured by auscultation, but with the refinement introduced by Doppler echocardiography, it is now possible accurately to diagnose even the smallest of patent arterial ducts.[3] To this day, the indications for treatment are to eliminate both pulmonary overcirculation, and the risk of developing endocarditis.[4] It was not until Gross and Hubbard,[5] in 1939, described the first successful surgical closure of a patent arterial duct that therapy became a reality. In the intervening years, surgical procedures were refined and improved, but for several decades they remained the only practical means of closing the persistently patent arterial channel. The next important modification in the surgical approach occurred in 1991, when Laborde and associates, in Paris,[6,7] showed that the duct could be closed by means of video assisted thoracoscopic surgery, this approach then being endorsed by Burke and his colleagues.[8,9]

By that time, however, catheter-derived therapies had already begun to offer alternatives to the surgical approach. Thus, already in 1971 Porstmann and colleagues[10] had described using an Ivalon plug to achieve non-surgical closure. Then, in 1979, Rashkind and colleagues[11] reported the successful deployment of a percutaneously delivered double disk device in an infant weighing only 3.5 kilograms. Shortly thereafter, Cambier and colleagues[12] described a simple technique for successful closure of small ducts using readily available stainless steel coils. In several institutions, as experience was gained by interventional cardiologists in the use of percutaneous techniques, predominantly employing embolization of coils, and by surgeons utilizing the minimally invasive endoscopic approach, these two techniques became complementary, with the smaller ducts closed with coils, and the larger ones interrupted by video assisted ligation, and occasionally by open thoracotomy.[13,14] In 2003, in the United States of America, the Food and Drug Administration approved the use of the Amplatzer Duct Occluder. Use of this device, which had been available much earlier outside of the United States of America, permitted closure of larger arterial ducts, even as large as 16 millimetres in diameter. The advent of the new technology has now increased the proportion of patients who undergo successful percutaneous closure.[1]

Techniques for closure

Over the years that these procedures have been performed at the affiliated institutions associated

with the Congenital Heart Institute of Florida, we have adopted an approach that has capitalized on the complementary roles of occlusion via interventional cardiology, video-assisted thoracoscopic surgery, and conventional surgical approaches.[14]

Interventional closure

For the percutaneous approach performed in the catheterization laboratory, a paediatric anaesthesiologist controls the airway, and either conscious sedation or a general anaesthetic is given according to the needs of the patient and the judgment of the anaesthesiologist. Arterial and venous access, preferably from the femoral vessels, is obtained in almost all cases. Typically, a 4 French sheath is placed into the artery, and a 6 French sheath into the vein. A standard catheterization is then performed. Heparin and antibiotic prophylaxis are given at the appropriate times. The internal diameter of the patent arterial duct is estimated by angiography. If the diameter of the duct is larger than 2 to 3 millimetres, we use an Amplatzer occluder, which is delivered through the pulmonary trunk in the standard fashion as recommended by the manufacturer.[15] For smaller ducts, we insert a single stainless steel coil, manufactured by Cook Incorporated, measured to be 1.5 to 2 times the size of the "neck" of the duct. It is delivered from the aortic side, with one loop placed on the pulmonary side of the duct, and the remaining loops in the ampulla. For the slightly larger duct, which is considered too small for the use of the Amplatzer occluder, the duct is cannulated simultaneously from the pulmonary and the aortic sides. A detachable coil is placed from the pulmonary side, and another coil from the aortic side. If necessary, further coils are used to affect closure.[14]

Video-assisted thoracoscopic surgery

Surgical procedures are typically carried out in the operating room, and under general anaesthesia. The patient is intubated with a single-lumen endotracheal tube, and placed in the right lateral decubitus position. For larger patients, double lumen endotracheal intubation is used, with selective ventilation of the right lung. Routine monitoring includes measurements of transcutaneous saturations of oxygen, continuous end-tidal carbon dioxide, blood pressure, and the electrocardiogram. Four small thoracostomies are made in the posterolateral chest wall to admit trocars to facilitate insertion of a 2.7 millimetre grasping forceps, an expanding lung retractor or cotton swabs for retraction of the lung in infants weighing less than 4,000 grams, and a 30 degree angled videoscope that is 4 millimetres in size in infants weighing more than 4,000 grams, and 2.7 millimetres in size for infants weighing less than 4,000 grams (Karl Storz Endoscopy, Culver City, CA). The posterior port admits an l-shaped cautery dissector, and the device for applying the clip. It is not necessary to cut the muscles of the chest wall, and the ribs are not retracted. Exposure is achieved by retracting the inflated left upper lobe inferomedially. The parietal pleura overlying the duct is opened, and the crossing vein is divided between clips. The upper and lower angles of the duct are dissected free, taking care to protect the vagus and recurrent laryngeal nerves, which are easily visualized. A mechanical arm holds the videoscope in position, providing stable images and reducing obstruction in the operative field. One or two endoscopic vascular clips are placed to interrupt the duct. Alternatively, intracorporeal ligation is possible, and is facilitated by creating an extracorporeal knot and using a knot pusher. A large duct may be reduced in size with an intracorporeal knot, and then completely occluded with a clip. The pleural edges are cauterized to prevent chylous leak. A thoracostomy tube is placed through one of the ports while the others are closed. The lung is re-expanded, and the thoracostomy tube is removed in the operating room. A plain X-ray is obtained before leaving the operating theatre to confirm the absence of pneumothorax. Except for patients on mechanical ventilation preoperatively, patients are routinely extubated in the operating theatre. The chest film is repeated the next morning, and the patient is discharged. Equipment is readily available in the operating theatre for rapid conversion to thoracotomy to control bleeding. Conversion to thoracotomy because of bleeding, however, is extremely rare. For video assisted ductal closure, echocardiography is performed in the operating theatre to confirm the absence of residual ductal flow. Transthoracic echocardiography, with the probe in a sterile lubricated tube, and transesophageal echocardiography have been each used at times, depending on the size of the patient and the preference of the cardiologist.

Conventional thoracotomy

For those undergoing a muscle sparing thoracotomy, a limited left posterolateral thoracotomy is performed, with subtotal division of the latissimus dorsi muscle, or complete sparing of the latissimus dorsi muscle, along with sparing of the serratus anterior muscle. The pleural space is entered through the fourth intercostal space. Exposure is achieved by retracting the inflated left upper lobe

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inferomedially. The parietal pleura overlying the duct is opened, and the crossing vein is divided. The upper and lower angles of the duct are dissected free, taking care to protect the vagus and recurrent laryngeal nerves. Depending on size of the patient and the duct, the duct may be either divided between ligatures, or ligated with either one or two silk ligatures or one or two vascular clips. The pleural edges are cauterized to prevent chylous leak, and sometimes the pleura is closed. On occasion, we may place a thoracostomy tube.

Evolution of strategies

In 2003, we published our strategy for management of the patent arterial duct at the Congenital Heart Institute of Florida, based on our experience to that date with occlusion using coils and video assisted surgical ligation in a cohort of 141 consecutive children.[14] At that time, we made the following four recommendations:

- First, treatment of the haemodynamically significant patent arterial duct in small premature infants involves initial anticongestive treatment followed by an attempt at chemical closure with medicines such as indomethacin. An operation is utilized when indomethacin therapy is ineffective or contraindicated.
- Second, full-term otherwise healthy infants less than 1 year of age are best treated with video assisted surgical ductal ligation. A large infant weighing more than 10 kilograms might be a candidate for occlusion using coils, but in smaller infants we use minimally invasive surgical techniques because of the potential of arterial complications when inserting coils.
- Third, older children and adults can be treated with minimally invasive surgical techniques, open surgical techniques, or transcatheter occlusion with coils, depending on the situation. As the ratio of the size of the duct to the patient increases, transcatheter occlusion using coils becomes more cumbersome. At some point, this ratio is large enough that surgical ligation represents a better option than transcatheter occlusion. In 2003, our approach was based on echocardiographic criterions that to be considered for occlusion using coils, or by video assistance, the patient should not have a short and wide "window-like" duct, for children weighing more than 10 kilograms occlusion using coils was favoured if the ductal diameter was less than 2.5 millimetres, for duct measuring between 2.5 and 3.0 millimetres the decision was based on the size of the patient size and the morphology of the duct, and surgical closure, often with video assistance was used for ducts greater than 3.0 millimetres in diameter.
- Fourth, patients with calcified ducts, severe pleural scarring, or short, wide, window-like ducts who require surgery are not candidates for video assisted closure. When in need of surgery, these patients are best treated with open surgical techniques.

Since this publication,[14] our strategy has changed subsequent to the availability of the Amplatzer occluder.[1,15] This new device has allowed significantly larger patent arterial ducts to be closed with interventional catheterization procedures that in the past would have been closed at surgery. During the interval between 2002 and 2006 inclusive, the overall surgical volume at our Institute has been stable. Over this period, the number of patients undergoing surgical ligation of the patent arterial duct has decreased, with this decline in volume most notable for the subgroup of patients weighing more than five kilograms (Fig. 1). In Figure 2, we show the volume of all video assisted thoracoscopic procedures performed for closure of the persistently patent duct. An initial increase in procedural volume occurred as the procedure gained popularity. Later, as the techniques for transcatheter closure were expanded to include patents with larger ducts, the volume of video assisted procedures decreased. This decrease in thoracoscopic procedures is attributable to the increased ability to close larger ducts using the Amplatzer occluder.

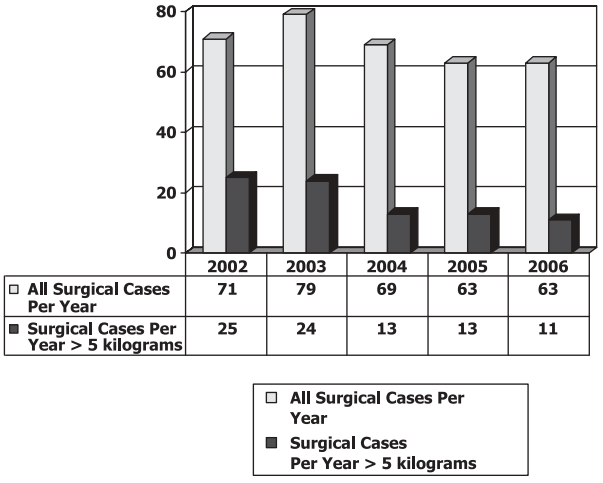

Figure 1.
During the interval from 2002 to 2006 inclusive, at The Congenital Heart Institute of Florida, the number of patients undergoing surgical ligation of the duct has decreased. This decline in volume has been most notable for the subgroup of patients weighing more than five kilograms.

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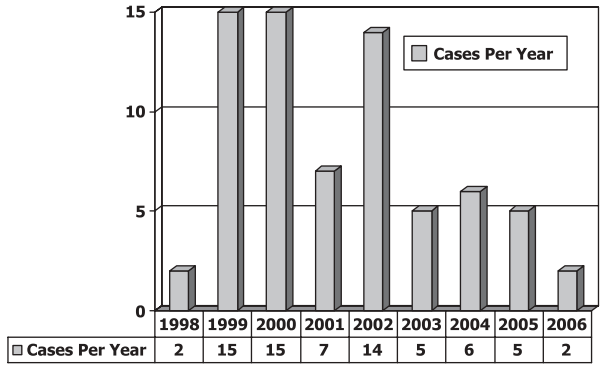

Figure 2.
The graph shows the volume of all video-assisted thoracoscopic procedures done at the Congenital Heart Institute of Florida for closure of the arterial duct. An initial increase in procedural volume occurred as the procedure gained popularity. Later, as the techniques for transcatheter closure of the arterial duct were expanded to permit closure of larger ducts, the volume of video-assisted procedures decreased. This decrease is attributable to the increased ability to close larger ducts using the Amplatzer occluder.

Outcomes

In 1994, Mavroudis and colleagues[16] reported their surgical experience with open thoracotomy in 1108 patients, having excluded premature infants, with no mortality and low morbidity. In 2003, when we published our experience of all of our patients with patent arterial duct treated with video-assisted thoracoscopic surgery or interventional occlusion, we analyzed 100 patients who underwent 102 cardiac catheterizations, and 45 children underwent a video assisted surgical approach. The entire cohort was made up of 141 patients, because 4 patients underwent both catheterization and video assisted surgery. We also encountered no mortality, and low morbidity.

Data collected by the "PDA Coil Registry" in 523 patients[17] documents no reported deaths, albeit with 19 complications. Most recently, Galal and colleagues[1] reviewed the experience with transcatheter closure of the arterial duct, and documented one death reported in a large multicentre study, and one death from a report from the National Institute for Clinical Excellence. The second of these deaths was documented in an analysis that reviewed several studies, and cited data for a total of 2317 patients that underwent closure either with coils or the Amplatzer device, the patient dying after insertion of an Amplatzer device. The total mortality reported to the National Institute for Clinical Excellence[18] was 1 patient out of 2317, or 0.04%. In addition, Galal and colleagues[1] also noted that, as technology continues to evolve, and experience with percutaneous closure continues to improve, the risk of unforeseen late complications has become increasingly less of an issue, particularly with percutaneous techniques.

Management of the silent patent arterial duct

The traditional management of the clinically audible patent arterial duct with closure, either with surgical or more recently, catheter derived techniques, has been the mainstay of treatment, and is now widely accepted by cardiologists and surgeons. The reason for intervention has been control of symptomatic pulmonary over-circulation in those patients with significant shunting, and prevention of endocarditis in all. More recently, the treatment of the so-called "silent" duct has generated significant controversy. This entity is defined as persistent patency of a duct, but without the typical continuous murmur. It is likely a common phenomenon, and according to some authors, not associated with an increased risk of endocarditis.[3,19–21] Indeed, the consensus reached at the conference of the Canadian Cardiovascular Society in 2001 clearly states that, "No intervention is indicated if a small silent PDA is detected".[22]

In 2005, in a study of patients with congenital cardiac disease and endocarditis, Kiwa and colleagues[23] reported the results of a Japanese national collaboration study in 239 patients, of whom more than two-thirds were children. In their conclusions they noted an "increase in the incidence of infective endocarditis and high mortality and complication rate". Furthermore, from this and other publications, it is recognized that not all cases of endocarditis are caused by a dental or surgical procedure, and the rate of "spontaneous" endocarditis, that is endocarditis with no precipitating procedure or event, can be very high, ranging from 67 to 94 percent.[23–25]

The improvements in techniques for ductal interruption, predominantly transcatheter derived but surgical as well, and the very low risk of mortality associated with these procedures, have led us at our Institute to question the recommendations not to close the silent but patent arterial duct. We do recognize that the risk of endocarditis is very low, but we do not believe that this risk is the same as in the individual with a normal heart. The devastating effects of endocarditis, coupled with the perception of more anecdotal reports of endocarditis with the silent duct,[26–30] as well as the low risk of interventions, has led us to intervene in these situations. Thus, we now recommend intervention, after informed consent, for all patients with a patent arterial duct regardless of size, including those in which the patent duct is "silent". We recognize,

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however, that this remains a controversial topic, especially given the new recommendations for endocarditis prophylaxis from American Heart Association.[31]

We have been influenced by two changes in our philosophy. The first is that, as experience accumulates with catheter derived therapy and alternative surgical approaches, the decreasing incidence of morbidity and mortality with intervention, combined with the serious consequences associated with an episode of endocarditis, makes the risk of an intervention an acceptable alternative. The other is the realization, from the perspective of the parent, that the concept of "delayed risk" versus "immediate risk" plays a very important role in the process of decision making. For many parents, this concept is a very important consideration. From this perspective, the risk of closure is a singular event where all the risk is peri-procedural and "immediate". From both our perspective, and that of the parents, this "singular" intervention avoids the uncertainty associated with the possibility of an unpreventable episode of endocarditis in the individual with a patent arterial duct.

Summary and recommendations for management

At the Congenital Heart Institute of Florida, we now recommend closure of all patent arterial ducts, regardless of their size. Before selecting and performing the type of procedure, we explain the natural history of the persistently patent arterial duct to the parents or legal guardian of the child. Particular emphasis is placed on the risks of endocarditis, including the recognition that many cases of endocarditis may not be preventable. Given the lesser cost,[20] morbidity, and mortality of catheter-derived therapy, we currently recommend percutaneous closure for all patent arterial ducts as the first intervention, reserving surgical treatment for those cases that are not amenable to the percutaneous approach.

For infants with symptomatic pulmonary overcirculation weighing less than 5 kilograms, our preference is for the surgical approach. For patients who have ductal calcification, significant pleural scarring, or 'window-like' arterial ducts, video-assisted ligation is not an option and open surgical techniques are used. When video-assisted ligation is possible, the approach is based on family and surgeon preference. As our overall annual experience with video-assisted ligation diminishes, as discussed earlier in this manuscript, we have become less likely to use this technique even with smaller babies. When open thoracotomy is selected, we usually use a muscle-sparing left posterolateral thoracotomy.[14]

For symptomatic infants weighing greater than 5 kilogram with large ducts, we prefer to use the Amplatzer occluder. In rare instances, the size of the required ductal occluder is so large that either encroachment into the aorta or pulmonary arteries is noted, and the device is removed. The child is then referred for surgical closure. This phenomenon has decreased as we have gained experience with echocardiographic evaluation of the relationship between the size of the arterial duct and the surrounding vascular structures. We can now often predict via echocardiography that a duct is too large for transcatheter closure, even with the Amplatzer occluder, and refer these patients directly to surgery.

For patients with an asymptomatic patent arterial duct, we prefer to wait until the weight is from 10 to 12 kilograms, or they are closer to 2 years of age. It is our impression that complications with vascular access are lessened in the larger child, and the risk of endocarditis is very low in patients at this age. If the patent arterial duct is greater than 2.0 to 2.5 millimetres in diameter, our preference is to use the Amplatzer occluder. For smaller ducts, we typically use stainless steel coils. Using this strategy, we close all patent arterial ducts, regardless of their size.

References

1. Galal MO, Hussain A, Arfi A. Do we still need the surgeon to close the persistently patent arterial duct? Cardiol Young 2006; 16: 522–536.
2. Fransson SG. The Botallo Mystery (Profiles in Cardiology). Clin Cardiol 1999; 22: 434–436.
3. Houston AB, Gnanapragasam JP, Lim MK, Doig WB, Coleman EN. Doppler ultrasound and the silent ductus arteriosus. Br Heart J 1991; 65: 97–99.
4. Campbell M. Natural history of persistent ductus arteriosus. Br Heart J 1968; 30: 4–13.
5. Gross RE, Hubbard JP. Surgical ligation of a patent ductus arteriosus. JAMA 1939; 112: 729–731.
6. Laborde F, Noirhomme P, Karam J, Batisse A, Bourel P, Saint Maurice O. A new video-assisted thoracoscopic surgical technique for interruption of patent ductus arteriosus in infants and children. J Thorac Cardiovasc Surg 1993; 105: 278–280.
7. Laborde F, Folliquet T, Batisse A, Dibie A, da-Cruz E, Carbognani D. Video-assisted thoracoscopic surgical interruption: the technique of choice for patent ductus arteriosus. Routine experience in 230 pediatric cases. J Thorac Cardiovasc Surg 1995; 110: 1681–1684.
8. Burke RP, Wernovsky G, van der Velde M, Hansen D, Castaneda A. Video-assisted thoracoscopic surgery for congenital heart disease. J Thorac Cardiovasc Surg 1995; 109: 499–508.
9. Burke RP, Jacobs JP, Cheng W, Trento A, Fontana GP. Video-assisted thoracoscopic surgery for patent ductus arteriosus in low-birth-weight neonates and infants. Pediatrics 1999; 104: 227–230.
10. Wierny L, Plass R, Porstmann W. Transluminal closure of patent ductus arteriosus: long-term results of 208 cases treated

https://doi.org/10.1017/S1047951107001175 Published online by Cambridge University Press

without thoracotomy. Cardiovasc Intervent Radiol 1986; 9: 279–285.
11. Rashkind WJ, Mullins CE, Hellenbrand WE, Tait MA. Nonsurgical closure of patent ductus arteriosus: clinical application of the Rashkind PDA Occluder System. Circulation 1987; 75: 583–592.
12. Cambier PA, Kirby WC, Wortham DC, Moore JW. Percutaneous closure of the small (less than 2.5 mm) patent ductus arteriosus using coil embolization. Am J Cardiol 1992; 69: 815–816.
13. Radtke WA. Current therapy of the patent ductus arteriosus. Curr Opin Cardiol 1998; 13: 59–65.
14. Jacobs JP, Giroud JM, Quintessenza JA, et al. The modern approach to patent ductus arteriosus treatment: complementary roles of video-assisted thoracoscopic surgery (VATS) and interventional cardiology coil occlusion. Ann Thorac Surg 2003; 76: 1421–1428.
15. http://www.amplatzer.com/us/medical_professionals/ado_implant.html.
16. Mavroudis C, Backer CL, Gevitz M. Forty six years of patent ductus arteriosus division at Children's Memorial Hospital of Chicago. Standards for Comparison. Ann Surg 1994; 220: 402–410.
17. http://www.med.umich.edu/pdc/pdacoil/data.htm.
18. http://www.nice.org.uk/.
19. Lloyd TR, Beekman 3rd RH. Clinically silent patent ductus arteriosus. Am Heart J 1994; 127: 1664–1665.
20. Prieto LR, DeCamillo DM, Konrad DJ, Scalet-Longworth, Latson LA. Comparison of cost and clinical outcome between transcatheter coil occlusion and surgical closure of isolated patent ductus arteriosus. Pediatrics 1998; 101: 1020–1024.
21. Thilen U, Astrom-Olsson K. Does the risk of infective endocarditis justify routine patent ductus arteriosus closure? Eur Heart J 1997; 18: 503–506.
22. http://www.cachnet.org/managing_recomp1.html#patent.html.
23. Kiwa N, Nakazawa M, Tateno S, Yoshinaga M, Terai M. Infective endocarditis in congenital heart disease: Japanese national collaboration study. Heart 2005; 91: 795–800.
24. Durack DT. Prevention of infective endocarditis. NEJM 1995; 332: 38–44.
25. Lopez-Dupla M, Hernandez S, Olona M, et al. Clinical characteristics and outcome of infective endocarditis in individuals of the general population managed at a teaching hospital without cardiac surgery facilities. Study of 120 cases. Rev Esp Cardiol 2006; 59: 1131–1139.
26. Ozkokeli M, Ates M, Uslu N, Akcar M. Pulmonary and aortic valve endocarditis in an adult patient with silent patent ductus arteriosus. Jpn Heart J 2004; 45: 1057–1061.
27. Friedland IR, du Plessis J, Cilliers A. Cardiac complications in children with Staphylococcus aureus bacteremia. J Pediatr 1995; 127: 746–748.
28. Cerruto G, Mancuso L. Systemic and pulmonary embolization in a patient with patent ductus arteriosus. Eur J Echocardiogr 2005; 6: 376–378.
29. Parthenakis FI, Kanakaraki MK, Vardas PE. Images in cardiology: silent patent ductus arteriosus endocarditis. Heart 2000; 84: 619.
30. Yanyk A, Yetkin E, Lleri M, Yetkin G, Penen K, Goskel S. Vegetation due to Streptococcus viridans in the pulmonary artery in a child with patent ductus arteriosus. Int J Cardiol 2000; 72: 189–191.
31. Wilson W, Taubert KA, Gewitz M, et al. Prevention of infective endocarditis. Guidelines from the American Heart Association. A Guideline from the American Heart Association Rheumatic Fever, Endocarditis, and Kawasaki Disease Committee, Council on Cardiovascular Disease in the Young, and the Council on Clinical Cardiology, Council on Cardiovascular Surgery and Anesthesia, and the Quality of Care and Outcomes Research Interdisciplinary Working Group. Circulation. 2007 Apr 19; [Epub ahead of print].