Paediatrica Indonesiana

VOLUME 53 July • 2013 NUMBER 4

Original Article

# Transcatheter vs. surgical closure of patent ductus arteriosus: outcomes and cost analysis

**Mulyadi M Djer, Mochammading, Mardjanis Said**

## Abstract

***Background*** Patent ductus arterious (PDA) is a non-cyanotic congenital heart disease (CHD) caused by the patency of the arterial duct after birth. For the last three decades, management of PDA with transcatheter closure has been gaining popularity, including in developing countries. However its effectiveness in terms of clinical outcomes and cost may vary among center and has not been thoroughly evaluated yet in Indonesia.

***Objectives*** To compare the cost and clinical effectiveness of PDA closure using transcatheter approach compared to surgical ligation.

***Methods*** We performed a retrospective review on patients underwent either transcatheter or surgical closure of PDA between January 2000 and December 2006 in Cipto Mangunkusumo Hospital, Jakarta, Indonesia. Clinical outcomes as well as cost were compared using the student T-test and Chi-square for numerical and categorical variables, respectively

***Results*** During the study period, 89 patients underwent transcatheter closure using an *Amplatzer®* device occluder (ADO) device and 67 had surgical ligation. Successful PDA closure on first attempt was achieved in 87 (96%) and 63 (94%) children who underwent transcatheter and surgical closure, respectively (P=1.000). Two children with unsuccessful transcatheter closure eventually had their PDA closed by surgery, whereas one child with residual PDA after surgical closure had his PDA closed by coil. No residual PDA was found in the transcatheter closure group at one-week follow up. Duration of hospitalization was significantly less for patients having transcatheter closure compared to surgery [2.7 (SD 1.5) vs. 6.6 (SD 1.5) days, P<0.0001]. The cost for PDA closure with an *Amplatzer®* device was more expensive than surgical ligation [Rp. 29,930,000 (SD 57,200) vs. Rp. 12,205,000 (SD 89,300), P< 0.0001].

***Conclusion*** Transcatheter closure is equally effective as surgical ligation in closing the PDA. Less hospitalization is required with transcatheter closure although the cost is higher than surgical ligation. **[Paediatr Indones. 2013;53:239-44.]**.

***Keywords:*** *persistent ductus arteriosus, Amplatzer® duct occluder, surgical ligation, cost analysis*

Patent ductus arterious (PDA) is a non-cyanotic congenital heart disease (CHD) caused by the patency of arterial duct after birth.[1-4] In the presence of PDA, a closure is currently almost always indicated, especially for the moderate to large PDA, to prevent or treat symptoms associated with this lesion.

Non-surgical approach for PDA closure using percutaneous transcatheter procedure has been advocated in the last three decades.[5-7] One of the most popular device used for the transcatheter closure is the *Amplatzer®* duct occluder or ADO (*AGA Medical Co, Golden Valley, MN, US*) which had been recommended by *Food and Drugs Association (FDA) US* since the year of 1998.[8]

Previous studies reported that the rate of complete closure by ADO is between 80-99%.[5-9] This procedure is mostly preferable over surgery because it is less invasive and results in minimal complication, fewer hospitalization days, and without surgery scar.[10-15] However, there are also concerns about higher cost put by the PDA transcatheter closure procedure, which may differ among centers.[16-17] Since clinical

From the Department of Child Health, University of Indonesia Medical School, Cipto Mangunkusumo Hospital, Jakarta, Indonesia

**Reprint requests to:** Mulyadi M. Djer, Pediatric Cardiology Division, Department of Child Health, University of Indonesia Medical School/ Cipto Mangunkusumo Hospital, Jl. Diponegoro 71 Jakarta. E-mail: muldjer@yahoo.com.

outcomes and cost are very important in a health decision-making process, we set out to evaluate the outcomes and cost of PDA closure by transcatheter methods using ADO device compared to surgical ligation.

## Methods

We performed a retrospective review on all patients indicated for PDA closure between January 2000 and December 2006 in Cipto Mangunkusumo Hospital, Jakarta, Indonesia. We included patients aged between 6 months and 17 years with PDA diagnosed based on pre-operative echocardiography and weighed at least 5 kg. We excluded all patients with duct dependent lesions, with PDA associated with complex CHD, or those with multiple congenital anomalies.

The primary outcomes of this study were immediate efficacy, short-term complications, and direct cost of PDA transcatheter closure compared to surgical ligation. The PDA transcatheter closure procedures were started to be performed in our center in 2002, whereas surgery had been done since 2000. We collected the following data from the medical records: age, immediate results (complete or incomplete closure) at discharge, rate of closure in 7 days after the procedure, complications during the procedure and hospitalization, length of stay, and the presence of residual PDA. Complications were classified as major (death, cardiac tamponade, cardiac arrest) and minor (transient badycardia or tachycardia).

The procedure cost was analyzed using the cost minimization analysis method.[18] Direct medical cost was calculated for the duration of hospitalization, hardware cost (catheterization laboratory operational cost, ADO device, anaesthesia drugs, pharmaceutical cost), laboratory and imaging investigations.. All values were expressed in Indonesian Rupiah (Rp). Indirect medical costs and professional fee were not included in the cost analysis.

We aimed to compare the outcomes and cost of transcatheter PDA closure using transcatheter versus surgical ligation. We used the student T-test and Chi-square for numerical and categorical variables, respectively. All statistical analyses were done using an *SPSS for Windows version 17* computer software program.

## Results

Between the year of 2000 and 2006, there were 156 patients with PDA underwent PDA closure procedures, of whom 89 underwent transcatheter closure and 67 had surgical ligation. The median age of the patients in the transcatheter closure group was significantly older from that of the surgery group (**Table 1**), which was 4 (range 0.6 to 13) years compared to 1.8 (range 0.6 to 12) years. On the other hand, the median duct size in the transcatheter closure group was smaller, which was two-thirds of the median size in the surgery group. In terms of procedure duration, no statistical significant difference was found between PDA transcatheter closure and surgery, which was approximately 75 minutes.

**Table 2** describes the clinical outcomes of PDA transcatheter closure using an ADO device compared to surgery**.** The rate of complete closure at discharge was slightly better in the transcatheter closure group compared to surgery (96% versus 94%), but this was not statistically significant. In the transcatheter closure group, 2 children (2%)

**Table 1.** Characteristics of the study subjects.

| Characteristics | Procedures | |
|---|---|---|
| | Transcatheter closure (n = 89) | Surgical ligation (n = 67) |
| Gender | | |
| Males, n (%) | 21 (24) | 21 (31) |
| Median age (range), years* | 4 (0.5–13) | 1.8 (0.5–12) |
| Median procedure time (range), minutes | 70 (45–165) | 75 (30–240) |
| Median weight (range), kg* | 13 (4.5– 33) | 8 (2.1– 33) |
| Median diameter of PDA (range), mm* | 4 (1.3–13) | 6 (3–11) |

* P value <0.001 with Mann Whitney test.

still had small residual shunt; while 2 had their device embolized so they were referred for surgery. Four children (6%) in the surgery group still had small residual shunt, but they were decided to be discharged for further observation.

On the follow up at 7 days after discharge, the rate of complete closure increased to approximately 98% in both groups (P = 1.00). Two and three patients with small residual shunt from the transcatheter closure and surgery group, respectively, eventually achieved complete closure. One patient who still had persistent shunt after surgical PDA ligation finally had his residual PDA closed transcatheterly using a coil.

No statistical significant difference was found in terms of complication rate between the two groups, however the duration of hospitalization was significantly lower in the transcatheter closure group compared to surgery [2.7 (SD 1.5) vs. 6.6 (SD 1.5) days, P<0.0001]. Two patients, one from each group, had fever after the PDA closure and were treated with antibiotics.

**Table 3** presents the details of total direct cost of transcatheter closure compared to surgical procedures.

Overall, the transcatheter closure costed higher than that of surgery. However this higher cost was mostly attributed to the cost for supporting operation facilities, such as the catheterization laboratory along with its equipment and the ADO device. On the other hand, the costs for hospitalization, pharmacy, and laboratory examination were significantly lower in the transcatheter closure group compared to surgery (P<0.0001). Even, the hospitalization and pharmaceutical costs for transcatheter closure was only around one-tenth of the corresponding costs put by surgery (P< 0.001).

**Table 2.** Clinical outcomes of transcatheter closure vs. surgical ligation

| Clinical outcomes | Procedures | | P value |
|---|---|---|---|
| | Transcatheter closure (n = 89) | Surgical ligation (n = 67) | |
| Result at discharge (>24 hr), n (%) | | | 1.000‡ |
| Complete closure | 85 (96) | 63 (94) | |
| Small residual shunt | 2 (2) | 4 (6) | |
| Large residual shunt | 0 (0.0) | 0 (0.0) | |
| Migration/embolization | 2 (2)‡‡ | - | |
| Result on follow-up (± 7 days), n (%) | | | 1.000‡ |
| Complete closure | 87 (98) | 66 (98) | |
| Small residual shunt | 0 (0.0) | 1 (2)* | |
| Large residual shunt | 0 (0.0) | 0 (0.0) | |
| Migration/embolization | 0 (0.0) | - | |
| Complications, n (%) | | | |
| No complication | 86 (97) | 64 (96) | 1.000‡ |
| Minor complication | 1 (1) | 2 (3) | |
| Mayor complication | - | - | |
| Mean hospitalization day (SD), days** | 2.7 (SD 1.5) | 6.6 (SD 1.5) | <0.0001 |
| Death †, n (%) | 0 (0) | 2 (3) | 1.000‡ |

‡P value of chi-square test;‡‡ Migration and embolization device, referred for surgical ligation; *persistent residual shunt and referred for coil occlusion; ** result expressed as mean ±standard deviation, P value for T test for independent sample; † caused complication.

**Table 3.** Cost comparison of transcatheter closure vs. surgical ligation

| Type of cost (Rp, x 1000) | Procedures | | P value |
|---|---|---|---|
| | Transcatheter closure (n = 89) | Surgical ligation (n = 67) | |
| SOF cost | 29,021 | 11,083 | N/A |
| Median hospitalization cost (range) | 166 (83 – 1,245) | 1,825(1,576– 22,643) | P< 0.0001‡ |
| Median pharmaceutical cost (range) | 332 (7.3 – 2,490) | 3,650 (3,152 – 45,286) | P< 0.0001‡ |
| Mean laboratory cost (SD) | 847.7 (SD 57.2) | 1,033 (SD 89.25) | P<0.0001** |
| Mean total cost (SD) | 29,930 (SD 57.2) | 12,205 (SD 89.3) | |

SOF, supporting operation facilities; *N/A, not applicable; ‡Mann Whitney test;** independent T test

## Discussion

In this study, we found that PDA closure using transcatheter methods was slightly more effective in achieving complete closure compared to surgery and required less hospitalization. However, this procedure resulted in higher total cost than surgery.

A decision for planning PDA transcatheter closure should be based on several clinical considerations, including patient'sage, size of the duct, and the possibility of complications. In this study, patients who underwent transcatheter closure were older and had smaller PDA diameter compared to those who had surgery. However, some literatures state that transcatheter procedure is feasible for infants with age of at least 12 weeks, weight of minimum 5 kg, and PDA diameter of at least 2 mm.[11,19] On the other hand, in surgical ligation, age and weight is not an absolute consideration, so that it remains as the procedure of choice for some cases, such as premature infants who do not respond to indomethacin, patients with complications, or those who failed transcatheter closure approach.[2,13]

In terms of age, previous study reported various age and weight at transcatheter closure procedure.[20] Differ from our study, they reported almost comparable age between the transcatheter and surgery group, which was around 4-5 years or 7-9 years old.

It has been clear that the success of a transcatheter PDA closure procedure is not only determined by the skill of the operator, but also by the age of the patient and his/her PDA size. Other factors, such as the individual clinical conditions/comorbidities, such as pneumonia, or any severe symptom of heart failure may affect the choice of management. Surgical ligation is usually preferred over transcatheter closure when the above conditions limit the feasibility of transcatheter approach.

Whether or not a patient achieves complete closure reflects the effectiveness of PDA management. In this study, the transcatheter closure and surgical ligation showed similar results with the rate of complete closure was 98% and 99%, respectively. The results were almost the same with previous study[16] comparing surgical ligation with and transcatheter closure using Gianturco coils. In that study, both treatment approaches had 100% success rate, however their patients had smaller PDA diameter compared to ours. Another study reported that percutaneous transcatheter procedure is less effective compared to surgery with complete closure rates of 90% and 100%, respectively. However the number of patients in that study was limited.[20]

Patent ductus arterious complete closure may be achieved rapidly after surgical ligation and the outcomes is more determined by the ligation technique.[13-15] On the other hand, after a transcatheter closure using an ADO, it may take around 24 hours to obtain acomplete closure of the PDA.The thrombogenic polyester material in the inner part of an ADO needs certain period to induce complete thrombosis in the PDA surrounding area.[21-23]

Accurate selection of the ADO size and delivery system (micro screw cable and delivery system) determine the success of the transcatheter closure. However, the procedure also requires high skill and experience, which improves as the number and type of cases handled increase.[21-23]

A multicentre study on the effectiveness of using ADO involving 439 children reported that immediate complete closure after transcatheter PDA closure procedure occurred in 76% of patients and it increased to 99% at the end of the study.[24] Residual shunt, which commonly occurs in surgical ligation, is probably related with the ligation technique used. Between the year of 2000 and 2006, ligation technique used by surgeons in our center was the double ligation technique. The disadvantage of this method was that the surgeon could not ligate a PDA too tight because of the potential rupture of the duct tissue due to its fragility.[25] Many studies have evaluated various ligation technique. A study in India[14] in January 2002 – December 2006 on 48 patients reported a 100% success rate of complete closure and minimal complication using multiple ligation technique and trans-fixation through transaxillaris thoracotomy. Previously, Mavroudis *et al* recommended ligation and division technique to manage PDA based on a 46-year study in Memorial Children's Hospital Chicago, USA, in 1108 children. It is suggested that the ligation and division technique is far better than ligation technique alone (0% vs. 5%) in achieving in acomplete closure.[13]

This study revealed that both the transcatheter procedure and surgery were safe, in which they resulted in minimal complication and no mortality.

The difference in length of stay between the two groups was more related to the choice of procedure. The ligation procedure is considered as a major surgery that demands close monitoring after surgery in intensive care unit (ICU). On the contrary, the transcatheter closure procedure is far less invasive. The monitoring and care after the procedure can be done in a regular ward and patients can be discharged within 24-48 hours if no complication occurs.

Cost minimization analysis is a method that only evaluates the total cost of interventions with equal clinical outcomes.[18] In this study, the surgical ligation procedure was found to be cheaper than the transcatheter closure using an ADO for a relatively equal clinical outcome. The main cost difference was on the operating/catheterization room (SOF) cost. The transcatheter closure procedure required an extra cost for the ADO (Rp. 19,500,000/unit or equal to USD 1950/unit in 2006), meaning that 65% of the SOF cost was allocated for the ADO unit. On the other hand, the ligation procedure does not need any extra equipment, so the cost is only allocated for the surgical procedure. Previous studies found similar results, either that used Gianturco coils[17] or Rashkind occluder.[25] Moreover, the total cost of Gianturco coil procedure was far higher than ligation [US$ 11,670 (SD 2,944) vs. 4,768 (SD 393)]. In contrast to the above studies, a study by Prieto *et al* in 1993-1996 found that the cost of transcatheter closure using coilswas less than surgery (US$ 5,273 vs US$ 8,509), which probably was attributed to the cheaper cost of coils and the use of local anesthesia in all patients.[16]

In the last decade, there was a change in the results of studies comparing the transcatheter and surgical procedures. A study in 1996-2002 comparing costs and clinical outcomes between surgical ligation and transcatheter procedure found no cost difference between the two procedures (US$ 4,690 vs US$ 4,667) with comparable effectiveness.[20] Another study in Australia, for atrial septal defect (ASD) closure using the *Amplatzer*® septal occlude (ASO) also found no difference in median cost between the transcatheter methods and surgery although the ASO device was expensive (Aus$ 12.969 vs. 11.845), which probably caused by higher cost of treatment, laboratory, and medication put by surgery. [25]

The results of the cost analysis in this study was largely influenced by the currency value of USD against Rupiah as we imported the ADO device. The calculation of the cost did not also include the use of anesthetics drugs, intravenous fluids, and disposable medical devices. If these costs were added to the procedure and hospitalization cost, the total cost of surgical ligation in our study might be greater than the ADO procedure. The results of the cost analysis might also be different if indirect cost was included in the study, such as the cost of patients' care giver and the loss of productivity of the family. Because it is a retrospective study, we can not calculate the indirect cost.

In conclusion, the effectiveness of transcatheter closure using ADO is similar to surgical ligation, but in terms of cost, it is not as efficient as surgical. The advantage of ADO procedure are related to shorter hospitalization days and less invasiveness and therefore it may be recommended as the primary choice for PDA treatment. A prospective study needs to be done in the future to assess the analysis of cost effectiveness incorporating the indirect cost.

## References

1. Fyler DC. Ductus ateriosus paten. In: Fyler DC, editors. Nadas pediatric cardiology. Boston: Hanley & Belfus.Inc; 1992. p. 598-608.
2. Hoffman JIE, Kaplan S. The incidence of congenital heart disease. J Am Coll Cardiol. 2002;39:890–900.
3. Musewe NN, Olley PM. Patent ductus arteriosus. In: Freedom RM, Benson LN, Smallhorn JF, editors. Neonatal heart disease. London: Springer-Verlag London; 1992. p. 593-609.
4. Schneider DJ, Moore JW. Patent ductus arteriosus. *Circulation.* 2006;114:1873-82.
5. Lloyd TR, Beekman RH. Transcatheter closure of atrial septal defect and patent ductus arteriosus. In: Topol EJ, editor. Texbook of interventional cardiology. 2nd edition. Philadelphia: WB Saunders; 1994. p. 298-338.
6. Rigby ML. Closure of the arterial duct: past, present, future. Heart. 1996;76:461-2.
7. Overmeire BV, Smets K, Lecoutere D, De Broek H, Weyler J, De Groote K, *et al*. A comparison of ibuprofen and indomethacin for closure of patent ductus erteriosus. N Engl J Med. 2000;343:674-81.
8. Donti A, Formigari R, Bonvicini M, Prandstraller D, Bronzetti

G. Transcatheter closure of the patent ductus arteriosus with new-generation devices: comparative data and follow-up results. Ital Heart J. 2002;3:122-7.

9. Bilkis AA, Alwi M, Harsi S, Haifa AL, Geetha K, Rehman MA. The Amplatzer duct occluder: experience in 209 patients. J Am Coll Cardiol. 2001;37:258–61.
10. Wong KT, Chau AKT, Cheung YF, Yung TC, Lun KS. Midterm results of transcatheter closure of moderate to large-sized patent ductus arteriosus using the Amplatzer duct occluder. HK J Pediatr. 2005;10:245-50.
11. Masura J, Walsh KP, Thanopoulous B, Chan C, Bass J, Goussous Y, *et al*. Catheter closure of moderate to large sized patent ductus arteriosus using the new Amplatzer duct occluder: immediate and short-term result. J Am Coll Cardiol. 1998;31:878-82.
12. Djer MM, Putra ST, Noormanto, Tobing T, Sukardi R, Sastroasmoro S. Transcatheter closure of patent ductus arteriosus: a two-year experience at Cipto Mangunkusumo hospital, Jakarta. Ind J Pediatr Cardiol. 2004;1:61-2.
13. 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;220:402–9.
14. Darbari A, Chandra G, Gupta A, Kumar A, Bharadwaj M, Tandon S. Clinical outcomes and experiences with trans-axillarysurgical ligation of patent ductus arteriosus. Ind J Thorac Cardiovasc Surg. 2007;23:197-201.
15. Zucker N, Qureshi SA, Baker EJ, Deverall PB, Tynan M. Residual patency of the arterial duct subsequent to surgical ligation. Cardiol Young. 1993;3: 216–9.
16. Prieto LR, De Camillo DM, Konrad DJ, Longworth LS, Latson LA. Comparison of cost and clinical outcome between transcatheter coil occlusion and surgical closure of isolated patent ductus arteriosus. J Pediatr. 1998;101:1020-4.
17. Fedderly R, Beekman RH, Mosca RS. Comparison of hospital charges for closure of patent ductus arteriosus by surgery and by transcatheter coil occlusion. Am J Cardiol. 1996;77:776–9.
18. Torgerson D, Campbell M. Cost effectiveness calculations and sample size. BMJ. 2000;321:696-7.
19. Fischer G, Stieh J, Uebing A, Grabitz R, Kramer HH. Transcatheter closure of persistent ductus arteriosus in infants using the Amplatzer duct occluder. Heart J. 2001;86:444-7.
20. Human DC, McIntyre L, Gniewek A, Hanna BD. Technology assessment of nonsurgical closure of patent ductus arteriosus: an evaluation of the clinical effectivenessand costs of a new medical device.Pediatrics.1995;96;703-6.
21. Masura J, Tittel P, Gavora P, Podnar T. Long-term outcome of transcatheter patent ductus arteriosus closure using Amplatzer duct occluders. Am Heart J. 2006;151:755.e7-10.
22. Pass RH, Hijazi Z, Hsu DT, Lewis V, Hellenbrand WE. Multicenter USA Amplatzer patent ductus arteriosus occlusion device trial: initial and one-year results. J Am Coll Cardiol. 2004;44:513-9.
23. Demir T, Öztunç F, Çetin G, Saltik L, Eroglu AG, Babaoglu K, *et al*. Patency or recanalization of the arterial duct after surgical double ligation and transfixion. Cardiol Young. 2007;17:48–50.
24. Gray DT, Weinstein MC. Decision and cost-utility analyses of surgical versus transcatheter closure of patent ductus arteriosus: should you let a smile be your umbrella. Med Decis Making. 1998;18:187-201.
25. Hughes ML, Maskell G, Goh TH, Wilkinson JL. Prospective comparison of costs and short term health outcomes of surgical versus device closure of atrial defect in children. Heart. 2002;88:67-70.