

## Comparison of Outcomes and Costs of Transcatheter Therapeutic Intervention and Surgical Ligation for the Treatment of Patent Ductus Arteriosus

### Dear Editor,

Patent ductus arteriosus (PDA) is a persistence of fetal communication, ductus arteriosus, which connects the aorta and pulmonary artery. One of the most common congenital heart conditions, PDA accounts for approximately 10% of all congenital heart defects.<sup>1</sup> Closure of the PDA (other than the silent duct) is recommended to prevent congestive heart failure, infection and pulmonary hypertension.<sup>2,3</sup> Methods to close PDA have evolved over the years with more options developed with similar safety and efficacy profile. This has opened up avenues for research, looking at not just clinical outcomes, but also taking into consideration costs, which may drive the selection strategy. Therefore, the need for local data on costs to guide practice and influence decision-making is imperative.

We aimed to compare the outcomes and cost of device closure through the transcatheter route using occluder device (ADO) versus surgical ligation (SL) in patients who underwent PDA corrective procedures.

### Materials and Methods

#### *Study Design and Population*

Two retrospective cohorts of patients who underwent PDA closure via SL or ADO closure, between February 2004 and April 2014 at the National University Hospital (NUH), Singapore were reviewed. Excluded were patients with concomitant pre-existing conditions, preterm infants or patients with other associated congenital heart defects who required interventions other than PDA closure. Patient diagnosis was confirmed on echocardiography with full colour flow mapping and Doppler studies. The study was approved by the Domain Specific Review Board.

#### *Treatment*

SL through conventional surgery and ADO closures in the cardiac catheter laboratory were performed under general anaesthesia. The clinical outcomes and complications, including minor (if resolved spontaneously or with minimal intervention) and major (if required a higher level of care or additional procedures) were recorded.

The cost was based on the final hospital financial bills of the patients, considering patients as paying ward B1

patients. This allows for a realistic comparison of the economic advantages of these methods by looking at the total costs incurred by the patient during the entire hospital stay. This cost computation comprised bed charges during the period of hospitalisation, pharmaceutical, diagnostic (echocardiography, laboratory and imaging studies), surgery or device cost, professional fees (cardiologist, surgeon, anaesthesiologist), operating theatre/cardiac catheterisation laboratory fees and other miscellaneous charges related to patient care. The cost estimations obtained in Singapore dollars were converted to US dollars (1 SGD = 0.70 USD), as per the conversion rate prevalent on 7 October 2015.

#### *Statistical Analysis*

The chi-square and one-way analysis of variance (ANOVA) were used for statistical analysis.

### Results

#### *Study Population*

Table 1 shows the comparative characteristics of 35 patients, 10 in the SL and 25 in ADO closure groups.

#### *Clinical Outcomes and Complications*

Successful closure of PDA was achieved in both groups with good clinical outcomes. All patients were discharged well. Post-procedure and follow-up echocardiogram at 6-months revealed complete ductal occlusion for all patients in both groups. The complication rate was significantly lower in patients who underwent ADO closure ( $P = 0.02$ ) (Table 1).

#### *Length of Stay (LOS) and Costs*

The mean length of stay (LOS) ( $6 \pm 2.4$  vs  $2 \pm 0.3$  days,  $P < 0.001$ ) and high dependency (HD) stay (80% with  $2.6 \pm 2.6$  days vs 20% with  $0.2 \pm 0.4$  days,  $P < 0.001$ ) was significantly longer in the SL group.

The mean cost per successful procedure (USD  $7716 \pm 4058$  vs USD  $6858 \pm 1639$ ,  $P = 0.37$ ), trended higher for SL than the ADO closure (Table 1). The cost of the ADO device and its delivery device (costing approximately USD 2600), contributed to a significant portion of the total

Table 1. Comparison of Demographic and Baseline Characteristics as well as Other Clinical Outcomes, Length of Stay and Charges between the Two Cohorts of PDA—ADO and SL

| Variables                                       | Total<br>(n = 35) | ADO Closure<br>(n = 25) | Surgical Ligation<br>(n = 10) | P Value |
|-------------------------------------------------|-------------------|-------------------------|-------------------------------|---------|
| Characteristics                                 |                   |                         |                               |         |
| Number of male patients (%)                     | 15 (42.9)         | 11 (44.0)               | 4 (40.0)                      | 0.05    |
|                                                 | Mean (SD)         |                         |                               |         |
| Age at time of operation, years                 | 7.0 (7.6)         | 9.0 (7.8)               | 2.0 (3.7)                     | 0.01*   |
| PDA size, mm                                    | 3.8 (1.3)         | 3.8 (1.3)               | 3.9 (1.2)                     | 0.69    |
| Body weight, kg                                 | 22.0 (9.5)        | 25.1 (9.0)              | 15.4 (7.2)                    | 0.01*   |
| LPA before catheterisation, m/s                 | 1.3 (0.3)         | 1.2 (0.3)               | 1.5 (0.3)                     | 0.02*   |
| Dao gradients before catheterisation, m/s       | 1.5 (0.5)         | 1.4 (0.3)               | 1.8 (0.6)                     | 0.06    |
| Complications                                   |                   |                         |                               |         |
| Number of patients with minor complications (%) | 6 (17.1)          | 2 <sup>†</sup> (8.0)    | 4 <sup>‡</sup> (40.0)         | 0.02*   |
| Clinical outcomes                               |                   |                         |                               |         |
| LPA after catheterisation, m/s                  | 1.1 (0.3)         | 1.1 (0.3)               | 1.2 (0.4)                     | 0.89    |
| Dao gradients after catheterisation, m/s        | 1.1 (0.3)         | 1.1 (0.3)               | 1.2 (0.3)                     | 0.70    |
| Length of stay                                  |                   |                         |                               |         |
| Hospital stay, days                             | 3.1 (2.2)         | 2.0 (0.3)               | 6.0 (2.4)                     | <0.001* |
| ICU/HD stay                                     |                   |                         |                               |         |
| Number of patients (%)                          | 13 (37.1)         | 5 (20.0)                | 8 (80.0)                      | <0.001* |
| Days                                            | 0.9 (1.8)         | 0.2 (0.4)               | 2.6 (2.6)                     | <0.001* |
| Total charges in SGD                            | 10109 (3603)      | 9760 (2333)             | 10981 (5775)                  | 0.37    |
| Total charges in USD                            | 7103 (2531)       | 6858 (1639)             | 7716 (4058)                   | 0.37    |

ADO: Amplatzer ductal occlude; Dao: Descending aorta; HD: High dependency; ICU: Intensive care unit; LPA: Left pulmonary artery; PDA: Patent ductus arteriosus; SD: Standard deviation

\*Statistically significant values.

<sup>†</sup>One was a case of mild postprocedural fever and the other had transient diminished pulse on lower extremity postdevice occlusion. Both resolved with no intervention required, other than antipyretics for the former.

<sup>‡</sup>Three of which were directly related to surgery. There was residual shunting noted on 2 cases; 1 had minimal pleural effusion and the other developed subcutaneous emphysema after chest tube removal which resolved. All the complications in these 4 cases did not require additional intervention or additional hospital stay.

hospitalisation bill incurred by patients who underwent ADO closure.

## Discussion

This is the first paper to our knowledge addressing cost considerations of this condition in Singapore. In other countries, conflicting cost analysis on SL versus ADO closure of PDA has been reported.<sup>4</sup> This is likely due to substantial heterogeneity among the studies in terms of PDA diameter, type of device used, patient characteristics, method of cost calculation, and more importantly, the period, as the cost of devices has gone down over time including less utilisation of medical resources due to improvement in the transcatheter procedure similar to our ASD study.<sup>5</sup>

Importantly in our study, there was no difference in terms of long-term successful closure of the PDA regardless of

the method, with no major complications. LOS and HD stay were significantly longer in the SL group. Although our study did not find a significant difference in the direct financial cost between the two interventions, the intangible cost associated with complications and LOS may incur a cost burden for the patients undergoing SL.<sup>6</sup> LOS is a key determinant of the other indirect costs such as work days off for parents and lodging/boarding/transportation cost. Reduction in hospitalisation and HD stay also poses less emotional stress on parents.<sup>4</sup> Furthermore, with ever increasing patient load and limited bed space in hospitals, a quick turnaround time will allow more patients to benefit from inpatient medical care and help the community as a whole.

One has to, however, keep in mind that there was a predilection for surgery in younger patients, with the majority of the patients <1 year in the SL group. This is

secondary to known technical difficulties. This includes the use of large devices in small infants which may protrude into the descending aorta or pulmonary artery.<sup>7</sup> Therefore, the use of ADO closure in patients weighing <5 kg is generally cautioned.<sup>8,9</sup> In our experience, ADO closure was successfully used for PDA sizes 2.5 to 8 mm, in agreement with previously published data on PDA up to 12 mm.<sup>10</sup> The prolonged HD stay in the surgical group could have been because of the younger group of children in SL group leading to more complications, requiring longer HD stay.

The cost outlined in the study is not an absolute cost but a relative cost used to compare the two interventions. The costs may vary in other healthcare systems, outside and within Singapore, where the professional and facility fees may differ. Another limitation is, over the study period of 10 years, there may have been inflation of healthcare costs which was difficult to account for. However, all else being equal, cosmesis and less postoperative pain are other important considerations.

## Conclusion

The corrective modalities discussed in this study were comparable in terms of effectiveness and safety profile for closure of isolated PDA. The ADO can be used for patients of varying ages, except small babies under 5 kg and small PDA. SL carries with it patient discomfort, longer stay and a surgical scar associated with an operative procedure, but nonetheless, will maintain its importance especially in the very small, such as premature babies.

## REFERENCES

1. Shim D, Beekman RH, 3rd. Transcatheter management of patent ductus arteriosus. *Pediatr Cardiol* 1998;19:67-71;discussion 72-3.
2. Campbell M. Natural history of persistent ductus arteriosus. *Br Heart J* 1968;30:4-13.
3. Tynan M. The ductus arteriosus and its closure. *N Engl J Med* 1993;329:1570-2.
4. Human DG, McIntyre L, Gniewek A, Hanna BD. Technology assessment of nonsurgical closure of patent ductus arteriosus: an evaluation of the clinical effectiveness and costs of a new medical device. *Pediatrics* 1995;96:703-6.
5. Quek SC, Hota S, Tai BC, Mujumdar S, Tok MY. Comparison of clinical outcomes and cost between surgical and transcatheter device closure of atrial septal defects in Singapore children. *Ann Acad Med Singapore* 2010;39:629-33.
6. Wang K, Pan X, Tang Q, Pang Y. Catheterization therapy vs surgical closure in pediatric patients with patent ductus arteriosus: a meta-analysis. *Clin Cardiol* 2014;37:188-94.
7. Tometzki AJ, Arnold R, Peart I, Sreeram N, Abdulhamed JM, Godman MJ, et al. Transcatheter occlusion of the patent ductus arteriosus with Cook detachable coils. *Heart* 1996;76:531-5.
8. Fernandez Ruiz A, del Cerro Marin MJ, Rubio Vidal D, Castro Gussoni MC, Moreno Granados F. Transcatheter closure of patent ductus arteriosus using the Amplatzer duct occluder: initial results and mid-term follow-up. *Rev Esp Cardiol* 2002;55:1057-62.
9. Chen Z, Chen L, Wu L. Transcatheter amplatzer occlusion and surgical closure of patent ductus arteriosus: comparison of effectiveness and costs in a low-income country. *Pediatr Cardiol* 2009;30:781-5.
10. 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.

Swee Chye Quek, <sup>1,2</sup>MD, FACC, FRCPCH, Diana Santos, <sup>3</sup>MBBS, Dimple Dayaram Rajgor, <sup>1,2</sup>PhD, Fan Yu, <sup>3</sup>MBBS, MPH, Robert Grignani, <sup>1,2</sup>MBBS, MRCPCH, DPhil

<sup>1</sup>Khoo Teck Puat-National University Children's Medical Institute, National University Health System, Singapore

<sup>2</sup>Department of Paediatrics, Yong Loo Lin School of Medicine, National University of Singapore, Singapore

<sup>3</sup>Department of Medical Affairs (Clinical Governance), National University Hospital, Singapore

Address for Correspondence: A/Prof Quek Swee Chye, Department of Paediatrics, National University Hospital, Singapore, Tower Block, Level 12, 1E Kent Ridge Road, Singapore 119228.

Email: swee\_chye\_quek@nuhs.edu.sg