CardioGRAFT-MC™ (also known as MatrACELL®) Decellularized Cardiac Patch Allograft Cost-Effectiveness Analysis

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ABSTRACT

Costs associated with health care continue to be of major concern within and outside of the United States. In the current health care environment, it is important for a new technology to demonstrate not only safety and effectiveness, but also that it is an economically viable treatment alternative. Health care policy decision-makers are increasingly considering the relative and comparative cost of a novel technology when making determinations regarding coverage.

Congenital heart defects are the most common type of birth defect, and their treatment is notoriously quite resource-intensive.[1] Pulmonary arterioplasty is frequently utilized as a treatment alternative for a variety of congenital heart conditions, though different patch materials are often applied, with little consensus as to the ideal patch material and composition. CardioGRAFT-MC (also known as MatrACELL**)** decellularized allogeneic non-valved pulmonary artery patches are a relatively new option, and offer a treatment alternative to traditional cryopreserved allogeneic patches and synthetic materials that have been plagued by various issues affecting their long-term durability. A prospective, post-market, nonrandomized, observational study evaluated midterm experience with CardioGRAFT-MC decellularized allogeneic patches used during congenital cardiac reconstructions.

Retrospectively reviewing facility data collected prospectively during this single center study of CardioGRAFT-MC decellularized Cardiac Allograft Bio-Implant, this analysis evaluated the cost-effectiveness of CardioGRAFT-MC decellularized allograft patches from a facility and health system perspective as compared with two alternative patch materials (cryopreserved allograft patches and synthetic patches) for right ventricular outflow tract reconstruction. This health economic analysis focused exclusively on downstream costs incurred for the treatment of reoperations and revision procedures that were attributable to the patch, as documented by the participating facility.

At this single center, the group treated with CardioGRAFT-MC decellularized patches experienced no device-related serious adverse events, device failures or evidence of calcification, while the comparative treatment group experienced an overall 14.0% patch failure rate requiring device-related reoperations.[2] These device-related reoperations—resulting in one of four specific procedures—varied in cost expended by the facility and depended on the precise procedure performed: **$50,221** for a catheter-based reoperation to address stenosis and replace a failed patch, **$72,381** for complete patch replacement, **$103,125** for a corrective procedure to address stenosis, and $**133,209** for the creation of a conduit to repair the right ventricular outflow tract. The applicable reimbursement received by the facility was often inadequate to fully compensate the hospital for the costs incurred in performing the device-related reoperation.

This analysis of CardioGRAFT-MC is intended to provide an economic context for the avoidance of reoperations and other post-operative interventions in order to demonstrate the cost savings to the facility and health system associated with the use of processed allograft patches. This study establishes that CardioGRAFT-MC decellularized allograft patches are the more cost-effective treatment option compared with cryopreserved allograft patches and synthetic patches.

[1] Pasquali SK, et al. *Variation in Congenital Heart Surgery Costs Across Hospitals.* Pediatrics. 2014,133(3): e553-e560.
[2] Hopkins RA, et al. *Pulmonary Arterioplasty with Decellularized Allogeneic Patches.* The Annals of Thoracic Surgery. 2014; 97(4): 1407-1412.

INTRODUCTION

In the current health care environment, it has become increasingly important to demonstrate that a new technology is not only safe and effective, but is also an economically viable treatment alternative. Today's health care policy decision-makers frequently consider the comparative cost-effectiveness of a novel technology when determining coverage access. Identifying less costly treatment alternatives for the repair of congenital heart defects is particularly critical, given that congenital heart defects account for the highest hospital charges associated with birth defects.[1,3]

Pulmonary arterioplasty—rebuilding of the pulmonary arteries—is frequently indicated for a variety of complex congenital heart defects. Though the procedure itself is widely accepted, many different materials are used for the cardiac reconstruction, including: synthetics (polytetrafluoroethylene), animal-derived bio-prosthetic, autologous tissue (pericardium), and cryopreserved allogenic (donated human tissue) conduit tissue. Currently, the most commonly used extracardiac patches are derived from autologous pericardium or cryopreserved allogenic tissues. Unfortunately, each of these patch options is plagued with various issues, and none possess ideal characteristics. For example, cryopreserved allogenic tissues have demonstrated variable success for the pediatric population due to the antigenicity of the cellular human tissue, resulting in calcification and stenosis (narrowing) of the graft and impeded growth of the arteries. Patches composed of synthetic materials tend to develop lumen peel and aneurysms, and can be pro-thrombotic (generating circulating blood clots).

The characteristics thought to optimize the initial surgical reconstruction aim to reduce the frequency of reoperations undertaken to preserve patency of these hypoplastic (small, underdeveloped and/or missing) vessels that often fail to grow at the repair sites. CardioGRAFT-MC decellularized allogeneic non-valved pulmonary artery patches for arterioplasty are a relatively new patch option for reconstruction of the right ventricular outflow tract that are thought to possess many of these ideal patch characteristics, this is because the donor cells that are antigenic, and cause calcification and stenosis have been removed.

CardioGRAFT-MC Decellularized Pulmonary Artery Patch Allograft was cleared by the U.S. Food and Drug Administration (FDA) on October 17, 2008 via the 510(k) pathway. In September 2009, MatrACELL processed pulmonary patch allografts became commercially available for surgical repair of the right ventricular outflow tract in patients of all ages.[4] CardioGRAFT-MC Decellularized Pulmonary Artery Patch Allograft is derived from donated human pulmonary artery tissue, and subsequently decellularized using the proprietary MatrACELL process, which renders the tissue acellular without compromising the biomechanical or biohospitable properties of the patch. CardioGRAFT-MC decellularized patches are provided in multiple sizes for clinical use. Clinical results from human subjects implanted with CardioGRAFT-MC decellularized patches have demonstrated the safety and effectiveness of the patch, as well as avoidance of various post-operative reoperations and patch replacements.

METHODS

This study is a retrospective health economic assessment reporting cost data for pulmonary arterioplasty procedures performed in neonates and infants at a single pediatric cardiovascular facility and involving one of three distinct patch materials. The original prospective, post-market approval, nonrandomized,

[3] Pasquali SK, et al. *Center Variation in Hospital Costs for Patients Undergoing Congenial Heart Surgery* Circ Cardiovascular Qual Outcomes. 2011;4: 306-312.

[4] Per the FDA label, CardioGRAFT-MC™ (also known as MatrACELL®**)** is indicated for repair of the right ventricular outflow tract. Available at: http://www.accessdata.fda.gov/cdrh_docs/pdf8/K081438.pdf

inclusive observational study reported midterm outcomes with the use of CardioGRAFT-MC decellularized pulmonary patch allografts in neonates and infants and compared these outcomes with data collected for a retrospective consecutive cohort of 100 subjects who received either traditional cryopreserved allograft patches or synthetic patches. Patients in this retrospective cohort were demographically similar to those subjects implanted with CardioGRAFT-MC processed pulmonary patch allografts.

Patients studied in this analysis were all treated at a single pediatric cardiovascular center for a variety of congenital heart defects requiring pulmonary arterioplasty. Data collected for this health economic analysis were derived from the single center experience, and included demographics information, certain peri-operative variables, post-operative complications, and all serious adverse events (as defined within the prospective trial).

MCRA performed a cost-avoidance analysis to demonstrate the cost savings associated with the CardioGRAFT-MC decellularized patches versus alternate patch options. Estimates will be derived from the analysis of historical surgical treatments (reoperations) for patients when the primary surgery fails. In order to derive health outcomes for this subset of patients treated with one of three patch alternatives, MCRA relied upon the patient outcomes reported by the participating pediatric cardiovascular service, as well as data documenting patch-related revisions and reoperations.

Costs are represented from a facility perspective, and were derived from the Healthcare Cost and Utilization Project (HCUP) 2009 Kids' Inpatient Database (KID) as published by the Agency for Healthcare Research and Quality.[5] The KID provides national estimates on hospital utilization by children ages 0-17, based on discharge data from 44 participating states. Costs included actual cost data as well as charges billed to third party payors (government and private) on both an annual and average per-patient basis. The HCUP 2009 KID permits the pulling of detailed statistics and cost data by specific diseases or conditions as well as specific surgeries performed, based on applicable coding. In retrieving data for this cost-avoidance analysis, MCRA analysts utilized applicable ICD-9-CM hospital procedure codes associated with each of four assumed reoperation procedures performed in order to address patch failure. The ICD-9-CM code set contains hospital procedure codes that report the procedures provided to the patient during the hospital stay and also factors into the MS-DRG assignment. All costs were converted to 2014 dollars.

MCRA certified coders provided four coding scenarios for patch failure resulting in reoperation in order to represent a variety of the reoperation and revisions procedures undertaken. Costs are intended to represent the hospital perspective for actual costs, as well as charges billed to third party payors, and have been filtered to account only for patients less than 1 year of age. Consideration of reimbursement received by the facility for the four reoperation scenarios has also been included, using 2014 Medicare national average payment rates as a benchmark. All reoperations or subsequent procedures undertaken to treat complications were assumed to have been be performed in the inpatient setting of care. Based on the four reoperation scenarios provided, MCRA certified coders mapped applicable ICD-9-CM hospital procedure codes to the likely Medical Severity Diagnosis Related Groups (MS-DRG).

[5] HCUP National Statistics on Kids Inpatient Database 2009. Available at: http://hcupnet.ahrq.gov/HCUPnet.jsp

RESULTS

Perioperative and Demographic Data

Data was available for a consecutive cohort of 106 subjects implanted with 118 CardioGRAFT-MC processed allograft patches, of which 100 patches were used for pulmonary arterioplasties. Data was also available for an immediately preceding retrospective consecutive cohort of patients treated at this same institution who received either traditional cryopreserved pulmonary artery allografts (59 patients and 59 patches) or synthetic patches (41 patients, 42 patches).

Amongst patients treated with the CardioGRAFT-MC decellularized patches, the mean age at the time of the index event was 367+/- 655 days. Average weight was 7.4+/- 6.17 kg, and this cohort had an average follow-up duration of 22 months. The average reported length of stay for all CardioGRAFT-MC patients was 61+/- 44 days, while average LOS was reduced to 29.7 +/- 43.9 days if only survivors to hospital discharged were considered.

Device-Related Serious Adverse Events

Study investigators participating in the prospective study of CardioGRAFT-MC decellularized patches captured all device- and non-device-related serious adverse events, including death, stenosis, and patch aneurysmal dilation. Catheter-based reinterventions, patch revisions or replacements and unanticipated (not staged) reoperations were also deemed serious adverse events. These events were all independently re-reviewed by three blinded cardiac surgeons and adjudicated as being related to the patch or not. This review included reassessment of postoperative angiograms, echocardiograms, CAT or MRI, reoperative surgical and catheterization reports, and chest x-rays.2

In the CardioGRAFT-MC decellularized patch cohort, there were no device failures or device-related serious adverse events reported through the average 28 months of follow-up. Specifically, there were no pulmonary artery aneurysms or stenoses that resulted in the replacement or catheter-based expansion of the CardioGRAFT-MC decellularized allograft patch, or could even be attributed to the patch.

In contrast, the retrospective cohort demonstrated an overall 14.0% patch failure rate that resulted in a device-related reoperation. The majority of these device-related reoperations occurred in patients implanted with cryopreserved allograft patches (20.3%). This failure rate occurred at a mean duration of 194 days +/- 104 days following the index event. Failure rates reported for patients implanted with the cryopreserved allograft patches were consistent with those reported elsewhere in the clinical literature, with concern often expressed for the HLA mediated immunogenicity of these cryopreserved allografts.[6,7,8] The failure rate for patients implanted with a synthetic patch (consisting of PTFE™) was 4.9% -- significantly lower than the cryopreserved allograft group, but still higher than the CardioGRAFT-MC cohort. The precise failure mode for each of the three groups is provided in Table 1:

[6]Clarke DR, Bishop DA. *Allograft degeneration in infant pulmonary valve allograft recipients.* European J Cardiothoracic Surg. 1993;7(7): 365-360.
[7] Hawkins JA, et al. *Midterm results with cryopreserved allograft valved conduits from the right ventricle to the pulmonary arteries.* J Thoracic Cardiovascular Surg. 1992 Oct; 104(4): 910-916.
[8] Shaddy RE, et al. *Prospective Analysis of HLA Immunogenicity of Cryopreserved Valved Allografts Used in Pediatric Heart Surgery.* Circulation. 1996; 94: 1063-1067.

Table 1: Failure Modes

	CardioGRAFT-MC	Cryopreserved	Synthetic
TOTAL Patches	**106**	**59**	**41**
Failure Mode	**N**	**N**	**N**
Stenosis	0	9	0
Pseudoaneurysm	0	0	2
Aneurysm + Stenosis	0	3	0
Total Patch Failures Resulting in Reoperation	**0**	**12**	**2**

The 0% patch failure and replacement rate for CardioGRAFT-MC decellularized allograft patches can be contrasted with the 4.9% failure rate for the synthetic patch cohort and even more starkly contrasted with the 20.3% failure rate reported amongst patients implanted with cryopreserved allograft patches. The failure modes reported indicate that synthetic patches may be more susceptible to pseudoaneurysm, while cryopreserved allograft patches trended towards stenosis.[2]

It is recognized that this patient population requires palliative or planned procedures; however, avoiding a reoperation or revision on the area originally corrected saves precious operating room time and most importantly can shorten the time the infant is on cardiopulmonary bypass, which likely decreases the patient's hospital length of stay (LOS).

Early outcomes following pulmonary artery reconstructions can impact a patient's future cardiovascular health.[9] For example, repair of lesions of the right ventricular outflow tract in infants have been found to create pulmonary valve incompetence that often requires valve replacement downstream.[10] These early reoperations and revisions undertaken to address patch failure have a grave clinical impact on subsequent patient health and can even impact patient mortality. Therefore, the absence of patch failure demonstrated in the CardioGRAFT-MC decellularized allograft patch cohort not only results in clinical benefit to the patient, but also translates into economic benefit to the facility and health care system as a whole.

DISCUSSION

Given the frequency, high cost and significant resource consumption associated with congenital heart defects, research has been conducted more recently to help understand important cost considerations and cost drivers for the various procedures performed to treat these conditions. Much of the current clinical literature focuses on analyzing the cost-effectiveness for various screening strategies or assessing the cost associated with particular surgical operations. While evidence reporting general cost-drivers and identifying the more costly congenital heart surgery procedures certainly exists, the authors are not aware of any evidence that more granularly analyzes comparative cost-effectiveness or how a particular procedure could vary in cost-effectiveness (i.e. through varying techniques, methods or products). In this health economic analysis, three patch materials utilized during pulmonary arterioplasty reconstruction in neonates and infants are examined from a cost-effectiveness and cost-avoidance perspective.

[9] Dragulescu A, Kammache I, Fouilloux V, et al. *Long-term results of pulmonary artery rehabilitation in patients with pulmonary atresia, ventricular septal defect, pulmonary artery hypoplasia, and major aortopulmonary collaterals.* J Thoracic Cardiovascular Surg. 2011; 142: 1374-80.

[10] Kirk RK, et al. *One Hundred Pulmonary Valve Replacements in Children After Relief of Right Ventricular Outflow Tract Obstruction.* Ann Thoracic Surg. 2002; 73: 1801-1807.

Data on hospitalization costs for individuals with congenital heart defects in the United States totaled approximately $1.4 billion, and severe congenital heart defects accounted for about $511 million, or about 37%, of the hospital costs associated with congenital heart defects.[11] Children with congenital heart conditions frequently require extensive initial lengths of stay and multiple hospitalizations over the course of the treatment continuum, which translates into higher health care expenditures. For example, a tetralogy of Fallot repair reportedly results in a hospital stay of between 7 days and 12 days.[3] Often the reoperation or revision procedure involves advanced surgical and interventional therapies, care by a multidisciplinary team, recurrent imaging and diagnostic testing, and a specific course of drug therapy.[3] To the extent that the number of reoperations can be reduced, costs associated with a particular procedure can also be mitigated.

A recent study by Pasquali *et al* seeking to establish cost benchmarks for a variety of the most common congenital heart operations supports this notion that reducing the occurrence of reoperations can significantly reduce cost. Pasquali and her colleagues linked clinical data obtained from the Society of Thoracic Surgeons Congenital Heart Surgery database[12] with administrative billing data from the Pediatric Health Information Systems database to describe costs for common congenital cardiac procedures and examine variety in cost between hospitals. After accounting for certain patient characteristics and patient mortality, the author found there was still a significant degree of variability between hospitals in terms of total costs for the same common congenital heart operations. Differences in hospital length of stay and postoperative complications accounted for 28% of this inter-hospital cost variation. Outcomes suggest that reducing complication rates can not only improve patient care, but can also decrease costs.[1]

In this current study, facility reporting of device-related reoperations and revisions was collected and retrospectively reviewed for patients treated with either CardioGRAFT-MC decellularized allograft patches, cryopreserved allograft patches, or a synthetic patch (mostly PTFE™). The device failure rate for the CardioGRAFT-MC cohort was 0%. In contrast, device failure rates for the cryopreserved and synthetic cohorts were 20.3% and 4.9%, respectively.

Patch failures can be directly tied to cost and resource expenditure from a hospital perspective, as these patch failures resulted in device-related reoperations/reinterventions for the retrospective cohort, which in turn translated into facility expenditure of time, resources and materials. In order to derive cost for these various reoperations, certified coders relied upon documentation provided by the participating facility in order to code for the reoperation or revision procedure that occurred to address the device-related failure modes documented above (stenosis, pseudoaneurysm, stenosis + aneurysm). Based upon data received, four reoperation scenarios were coded for in order to best account for the variety of patch-related reoperations/reinterventions that occurred. The first scenario denotes an open surgical procedure to replace the failed patch, and the second scenario involves a catheter-based revision to address stenosis and replacement of the failed patch. Scenario three denotes a corrective procedure to address stenosis, with patch replacement, and the fourth scenario denotes the creation of conduit to repair the right ventricular outflow tract and replace the patch. Applicable ICD-9-CM hospital procedure coding is provided for each type of reoperation, and these precise codes were used to pull the relevant cost data from the HCUP 2009 KID.

[11] Russo CA, Elixhauser A. Hospitalizations for Birth Defects, 2004. HCUP Statistical Brief #24. 2007. Rockville, MD, U.S. Agency for Healthcare Research and Quality.

[12] The STS Congenital Heart Surgery database is an extremely reputable and highly established data source that a majority of congenital heart programs enter procedural data into in order to drive best practices.

Scenario 1: Primary Procedure Using Patch Graft in Complete repair of Tetralogy of Fallot Procedure

The following depicts the likely ICD-9-CM hospital procedure coding for an open surgical procedure to replace a failed patch. Coding is not dependent on the precise patch materials used, so a reoperation to replace any of the three patch materials would result in the same ICD-9-CM hospital procedure coding.

Table 2: Scenario 1 Coding

ICD-9-CM Hospital Procedure Codes	
Code	**Description**
35.81	Total repair of tetralogy of Fallot
39.61	Extracorporeal circulation auxiliary to open heart surgery

Scenario 2: Catheter-Based Repair to Address System Following Tetralogy of Fallot Procedure

The following depicts ICD-9-CM hospital procedure coding for the second failure mode assumed: a catheter-based repair to address stenosis (with replacement of patch).

Table 3: Scenario 2 Coding

ICD-9-CM Hospital Procedure Codes	
Code	**Description**
37.23	Combined right and left heart cardiac catheterization
35.92	Creation of conduit between right ventricle and pulmonary artery

Scenario 3: Corrective Procedure to Address Stenosis

The following ICD-9-CM hospital procedure coding depicts the third scenario: a corrective procedure to address stenosis (with replacement of patch).

Table 4: Scenario 3 Coding

ICD-9-CM Hospital Procedure Codes	
Code	**Description**
35.95	Revision of corrective procedure on heart
39.61	Extracorporeal circulation auxiliary to open heart surgery

Scenario 4: Creation of Conduit to Repair Right Ventricular Outflow Tract

The following depicts ICD-9-CM hospital procedure coding for the fourth scenario: creation of a conduit for right ventricular outflow tract repair (with replacement of patch).

Table 5: Scenario 4 Coding

ICD-9-CM Hospital Procedure Codes	
Code	**Description**
35.92	Creation of conduit between right ventricle and pulmonary artery
39.61	Extracorporeal circulation auxiliary to open heart surgery

Regional and National Cost and Charge Data for Four Scenarios

Precise facility charge data was available for 7 of the 14 reoperation events that were deemed patch-related by the participating pediatric cardiovascular facility. This billed charge data has been provided in Table 6, and all charges have been converted to actual cost using the applicable cost-to-charge ratio.

Table 6: Facility Charge/Cost Data Reported

Patient	Failure Type	Length of Stay (Days)	Charges $	Cost[13] $
1	Aneurysm	320	$105,296	**$39,908**
2	Stenosis	307	$102,662	**$35, 362**
3	Aneurysm	222	$732,396	**$277,586**
4[14]	Aneurysm	287	$732,396	**$277,586**
5	Stenosis	186	$77,125	**$26,601**
6	Aneurysm	113	$160,312	**$60,760**
7	Stenosis	307	$101,993	**$35,131**

Because the reoperation data presented above and reported directly by the participating pediatric cardiovascular facility represents only a single center perspective, authors relied on the HCUP 2009 KID to supplement this single center charge and cost data with a more comprehensive national perspective.

National costs incurred were derived from the HCUP 2009 KID using the ICD-9-CM procedure coding depicted in the four scenarios detailed above, and represent the national perspective. Cost data retrieved from the HCUP 2009 KID included actual cost incurred by the facility as well as charges billed to third party payors (government and private) on both an annual and average per-patient basis. Total number of discharges and average lengths of stay were also retrieved from the HCUP 2009 KID. Table 7 depicts cost, charge and other discharge data obtained for the four reoperation/reinterventions scenarios.

[13] Cost data derived from the Charge data provided by the participating facility, using the applicable cost-to-charge ratio obtained from the HCUP 2009 KID.

[14] Patients 3 and 4 represent two reoperations occurring at different times on the same patient and during the same length of stay (i.e., two distinct patch failures within same patient). Billed charges were totaled for this patient and divided by the two reoperations, as it was not possible to separate which charge was associated with which reoperation event.

Table 7: HCUP Charge/Cost Data for Four Scenarios

Scenario1 Cost/Charge Data for ICD-9-CM Principal Procedure Codes 35.81, 39.61						
Code	**Total # of Discharges**	**Average LOS (days)**	**Charges $ (mean)**	**Costs $ (mean)**	**Aggregate Charges $**	**Aggregate Costs $**
35.81 39.61	1,264[15]	14.2	$213,728	**$72,381**	$270,261,696[16]	$91,429,586
Scenario 2 Cost, Charge Data for ICD-9-CM Principal Procedure Code 37.23, 35.92						
Code	**Total # of Discharges**	**Average LOS (days)**	**Charges $ (mean)**	**Costs $ (mean)**	**Aggregate Charges $**	**Aggregate Costs $**
37.23 35.92	1,040[17]	15.8	$144,807	**$50,221**	$189,071,271	$67,559,472
Scenario 3 Cost, Charge Data for ICD-9-CM Principal Procedure Codes 35.95, 39.61						
Code	**Total # of Discharges**	**Average LOS (days)**	**Charges $ (mean)**	**Costs $ (mean)**	**Aggregate Charges $**	**Aggregate Costs $**
35.95 39.61	24[18]	23.0	$299,392	**$103,125**	$5,377,865	$1,764,495
Scenario 4 Cost, Charge Data for ICD-9-CM Principal Procedure Codes 35.92, 39.61						
Code	**Total # of Discharges**	**Average LOS (days)**	**Charges $ (mean)**	**Costs $ (mean)**	**Aggregate Charges $**	**Aggregate Costs $**
35.92 39.61	315[19]	30.0	$351,466	**$133,209**	$108,961,020	$41,102,192[20]

The focus of this analysis is on the mean and aggregate cost incurred by the facility and expended by the health care system to address the failure modes described. Hospital charge data is still useful information, as it represents what a third party insurer is billed for a particular procedure. However, the cost data is more representative of resources expended and actual cost consumption by the facility for the specific procedure. These values are significant on a per-patient level: **$50,221** for a reoperation to address stenosis and replace a failed patch, **$72,381** for the complete patch replacement, **$103,125** for a corrective procedure to address stenosis, and $**133,209** for the creation of a conduit to repair the right ventricular outflow tract.

The cost to a facility and to the health care system becomes even more staggering when a larger volume of patients is considered, as evidenced by the aggregate costs displayed above. Of the 106 CardioGRAFT-MC decellularized patch subjects studied, not one patient experienced a device-related adverse event resulting any of the four reoperation scenarios depicted above. Thus, the costs described would not need

[15] 85.09% of children under 17 years of age were less than 1 year old.
[16] Aggregate cost and aggregate charge data only available for ICD-9 procedure code 35.81.
[17] 44.75% of children under 17 years of age were less than 1 year old.
[18] 27.13% of children under 17 years of age were less than 1 year old.
[19] 45.92% of children under 17 years of age were less than 1 year old.
[20] Aggregate cost and aggregate charge data only available for ICD-9 procedure code 35.92.

to be expended by the facility for a patient implanted with a CardioGRAFT-MC decellularized allograft patch. In contrast, 20.3% of the 59 patients receiving a cryopreserved allograft patch and 4.9% of the 41 patients receiving a synthetic patch underwent a device-related reoperation to address patch failure. Therefore, the health care system can achieve significant cost savings through the use of CardioGRAFT-MC decellularized allograft patches during a pulmonary arterioplasty over either of these patch material alternatives.

Impact of Reimbursement on Cost Data for Four Scenarios

The actual cost data for each of the four reoperation scenarios represents the cost incurred by the facility on a per-patient level without accounting for any reimbursement received from a third party heath plan. In order to provide a more complete account of facility expenditures for the various reoperation procedures, it is important to at least consider the impact of reimbursement and whether the payment value adequately makes the facility whole for resources expended.

Based on the four reoperation scenarios provided, MCRA certified coders mapped applicable ICD-9-CM hospital procedure codes to the likely MS-DRG, using 2014 Medicare national average payment rates as a benchmark. Medicare and many private payors use the MS-DRG based system to reimburse facilities for inpatient services, though distinct systems exist and will vary by private payor. In these alternate cases, reimbursement is determined on a case-by-case basis pursuant to the facility-payor contracted guidelines. Private payor reimbursement rates are derived from anecdotal information and are typically higher than Medicare reimbursement rates; a proxy of 120% of Medicare values has been provided to project private payor rates.

Medicare establishes MS-DRG groupings depending on the procedure performed, the individual's diagnosis, and the patient condition in order to provide a single reimbursement value for the entire inpatient stay. Certain MS-DRGs account for the possibility of complications and comorbidities present on arrival to the facility or arising during the case, which complicate the case and increase the hospital payment. With limited exceptions, the MS-DRG payment is inclusive of all services, products, and resources, regardless of the final cost to the hospital.

Table 8 provides the likely MS-DRG assignment, Medicare national average payment and commercial payment proxy for hospitals when performing the procedures depicted by Scenario 1, Scenario 3, and Scenario 4.

Table 8: MS-DRG Assignment

Hospital Inpatient MS-DRG Assignment			
MS-DRG	**MS-DRG Description**	**Medicare National Average Payment 2014**	**Commercial Payment Proxy (120%)**
228	Other Cardiothoracic Procedures with MCC	$36,884.16	$44,260.99
229	Other Cardiothoracic Procedures with CC	$23,851.02	$28,621.22
230	Other Cardiothoracic Procedures without CC/MCC	$19,692.28	$23,630.74

Scenario 2—denoted by ICD-9-CM 37.23—maps to MS-DRGs 218-216, as indicated in Table 9:

Table 9: MS-DRG Assignment

Hospital Inpatient MS-DRG Assignment			
MS-DRG	**MS-DRG Description**	**Medicare National Average Payment 2014**	**Commercial Payment Proxy (120%)**
216	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization with MCC	$50,910.79	$61,092.95
217	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization with CC	$33,744.15	$40,492.98
218	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization without CC/MCC	$29,140.21	$34,968.24

Again, certain MS-DRGs account for the possibility of complications and comorbidities present on arrival to the facility or arising during the case, which complicate the case and increase the hospital payment. An infant with a congenital heart condition would likely map to the higher MS-DRG, as the following table depicts:

Table 10: Facility Cost vs. Projected Reimbursement

Cost vs. Projected Reimbursement				
Scenario	**Average Cost (HCUP Data)**	**MS-DRG Assigned**	**Commercial Payment Proxy**	**Facility Cost after Reimbursement**
1	$72,381	228	$44,261	$28,120
2	$50,221	216	$61,093	($10,872)
3	$103,125	228	$44,261	$58,864
4	$133,209	228	$44,261	$88,948

As demonstrated above, the reimbursement received is generally inadequate in compensating the facility for the resources expended in performing each of the four reoperation procedures. In fact, the facility suffers a significant loss in undertaking three of the four procedures. Facilities therefore have a vested interest in selecting a patch material with the lowest rate of patch-related reoperations/reinterventions, given that costs incurred typically exceed reimbursement received.

Though this analysis is based on the experience of one pediatric cardiovascular service, the findings and conclusions are intended to demonstrate the relative cost-effectiveness of CardioGRAFT-MC decellularized patches over synthetic and cryopreserved allograft patches. Were patient volume to be increased beyond the 106 patients represented in this analysis, the possibility does exist that a patient implanted with CardioGRAFT-MC may ultimately require a reoperation to revise or replace a failed patch. However, this analysis is not intended to conclude that CardioGRAFT-MC decellularized allograft patch patients do not ever experience complications or patch failures, but rather, that rate of failure is

significantly lower than alternate patch materials, which results in clinical benefit to the patient as well substantial cost savings to the facility and the health system.

Furthermore, as reported as part of the prospective study of CardioGRAFT-MC decellularized allograft patches, the majority of patch failures occurred within one year.[2] The first 18 months following the initial surgical repair is an especially critical period for infants. This acute period marks the largest rate of somatic and cardiovascular allometric growth in infants, and is also the time during which pulmonary vessel stenosis and progressive hypoplasia are more probable.[2] Thus, with an average post-operative duration of 22 months, the CardioGRAFT-MC allograft patch cohort has already bypassed the period during which these serious complications are most aggressive and most likely.

CONCLUSION

This health economic analysis sought CardioGRAFT-MC to compare and analyze downstream costs incurred for the treatment of reoperations and revision procedures that were attributable to one of three distinct patch materials (synthetic, cryopreserved allogeneic, and decellularized allogeneic) used during a pulmonary arterioplasty reconstruction, as documented by a single pediatric cardiovascular facility.

CardioGRAFT-MC decellularized allograft patch patients experienced no device-related serious adverse events, device failures or evidence of calcification, while the comparative treatment group experienced an overall 14.0% patch failure rate requiring device-related reoperations (20% for cryopreserved allogeneic patches and 4.9% for synthetic patches). This avoidance of reoperations not only benefits the patient from a clinical perspective, but also resulted in significant cost savings to the facility.

Using cost and charge data derived from the HCUP 2009 KID, the four reoperation scenarios would cost a facility the following, on a per-patient basis: **$50,221** for a catheter-based repair to address stenosis and replace a failed patch, **$72,381** for the complete patch replacement, **$103,125** for a corrective procedure to address stenosis, and $**133,209** for the creation of a conduit to repair the right ventricular outflow tract. Furthermore, when examining typical reimbursement received by the hospital, costs incurred tended to exceed reimbursement received for the specific reoperations/reinterventions by 33-63%, resulting in a significant loss to the facility.

The CardioGRAFT-MC decellularized allograft patch has the potential to be a more cost-effective alternative and should be considered by health care facilities/system for use in their patients.