

Original Article

Cardiac catheterization in children as outpatients: potential, eligibility, safety and costs

Monica Arpagaus, Darryl Gray, Brenda Zierler

University Children's Hospital, Zurich, Switzerland; University of Washington; Seattle, Washington, USA

Abstract *Background:* Outcomes and costs of inpatient versus outpatient pediatric cardiac catheterization have not been extensively evaluated. *Methods:* For a cost-consequence analysis, we reviewed the medical records and cost data in a Swiss pediatric hospital. We compared outcomes and costs of observed inpatient management versus hypothetical planned same-day discharge for patients meeting the outpatient catheterization criteria for an American pediatric hospital. *Results:* Among 346 catheterization admissions occurring from January, 1998 through December, 1999, 179 met the American criteria for outpatient catheterization. Complications observed, and/or nursing interventions begun within 5 hours of catheterization, might have required overnight observation in 41 of the 179 admissions (22.9%). The remaining 138 patients were stable at five hours, and presumably could have been discharged the day of the procedure. Routine pre-discharge imaging detected significant complications following three interventional procedures. Postulated costs from the perspective of the provider, counting hospital and physician expenditure were calculated for the Swiss franc in 2000 at a rate of 1.69 francs for each American dollar, averaged 10,946 francs per inpatient, versus 9790 francs for outpatient treatment ($p < 0.001$ by paired t-test). Estimated revenue deficits, calculated as costs minus reimbursement, averaged 8565 francs per inpatient versus 1756 francs per patient treated as an outpatient. *Conclusions:* Half the patients being catheterized in the Swiss hospital met the external criteria for attempted outpatient catheterization. Most might have been safely discharged on the same day, with modest savings in costs, and reduced deficits in terms of revenue. Routine pre-discharge imaging may be more important than overnight observation. Outpatient catheterization merits prospective evaluation in Switzerland.

Keywords: Pediatric cardiology; pediatric cardiac catheterization; outpatient procedures; economic analysis; patient safety

WHILE CARDIAC CATHETERIZATION REMAINS an important diagnostic tool for managing children with cardiovascular disease, its focus is increasingly interventional.¹ Interventional procedures, including radio frequency catheter ablations, dilations of vessels and valves, closures of the patent arterial duct and atrial septal defects, embolizations of vessels, and implantation of stents, have reduced the need for surgical correction of many defects. Simultaneously, technological advances and

financial incentives have shifted provision of health care from the arena of the inpatient to that of ambulatory care.² Discussions with American and Canadian pediatric cardiologists indicate that outpatient diagnostic catheterization is considered routine. Policies regarding same-day discharge for interventional procedures, however, ranged from “almost never” to “almost always”, encouraging this approach. Data from the Pediatric Cardiac Care Consortium³ based in the United States for the calendar year 2000 indicates that roughly a third of admissions for interventional cardiac procedures in children now involve discharge on the same day (Virgil Larson, Pediatric Cardiac Care Consortium, personal communication, 2002).

At a leading children's hospital in the Pacific Northwest region of the United States of America, referred to subsequently as the American children's hospital, outpatient diagnostic and interventional

Correspondence to: Darryl T. Gray MD ScD, Research Assistant Professor of Health Services, Adjunct Research Assistant Professor of Pediatrics, University of Washington Box 358853, Center for Cost and Outcomes Research, 146 N Canal St Suite 300, Seattle, WA 98103, USA. Tel: +1 (206) 616-2140; Fax: +1 (206) 543-5318; E-mail: tolvadtg@u.washington.edu

Presented in part at the 2001 Annual Meeting, Third World Congress of Pediatric Cardiology and Cardiac Surgery, Toronto, Ontario, Canada.

Accepted for publication 3 January 2003

cardiac catheterization is performed on children meeting specific criteria. These children enter the hospital the morning of the catheterization and, barring any significant complications, leave five hours after the end of the procedure. In contrast, children undergoing cardiac catheterization at a leading children's hospital in Switzerland, hereto referred to as the Swiss children's hospital, enter the hospital the day before their procedure, and are discharged the day after their procedure. Swiss insurance policies include some fee for service, and some standardized reimbursement for each day of the stay, which may encourage prolonged hospitalization of some patients.

Despite a generally increasing emphasis on outpatient procedures, we identified no recent papers addressing the safety of outpatient cardiac catheterization in children. A study performed in 1982⁴ had concluded that diagnostic procedures involving catheterization might be safely performed in children on an outpatient basis. We performed this study, therefore, with two goals. The first was to determine the proportion of patients treated at the Swiss children's hospital that would meet the criteria of the American hospital for outpatient catheterization. The second was to consider potential costs and outcomes of this approach. We compared the costs associated with inpatient versus outpatient catheterization, and assess the likelihood that detection of their complications would have occurred before discharge planned for the same day.

Materials and methods

This retrospective cost-consequence comparison⁵ used the American hospital's model of care to determine potential clinical and cost implications of converting inpatient catheterization to an outpatient procedure. The University of Washington Human Subjects Committee and the Swiss Hospital approved the research protocol. Patient consent was not required.

Population studied

The cardiac catheterization logbook of the Swiss children's hospital was reviewed to identify all cardiac catheterizations performed from January 1998 through December 1999. Medical records were reviewed to identify cases that met the criteria for inclusion and exclusion established by the American children's hospital (Collette Fearneyhough, Seattle Children's Hospital and Regional Medical Center, personal communication, 2000). Criteria for inclusion were as follows:

- All diagnostic catheterizations performed on clinically stable children regardless of age, weight or

distance to the family home. The upper age limit for admission to the Swiss children's hospital is 16 years of age. Exceptions include older adolescents with known congenital problems that may be better managed in pediatric hospitals. Stable children could be medically managed on oral medication, but could not be in heart failure or receiving oxygen prior to the catheterization.

- Occlusions of vessels using coils or the Bard Patent Ductus Arteriosus Umbrella Device.
- Electrophysiology procedures including radio frequency catheter ablations.

Criteria for exclusion were:

- All clinically unstable patients, including those in heart failure or receiving intravenous medication or oxygen prior to the catheterization, or low weight cyanotic infants where adequate hydration is an issue.
- Any procedure or combination of procedures where dilation of a valve or vessel would result in increased blood flow to a previously stenotic area.
- Implantation of a device for closure of an atrial septal defect, intra-cardiac defibrillator, or pacemaker.
- Patients with primary pulmonary hypertension undergoing diagnostic catheterization using oxygen, nitrous oxide and prostin to test pulmonary vascular resistance.

Collection of data

Characteristics of patients

The following data were collected for patients meeting the criteria for inclusion: month and year of birth, gender, nationality, insurance type, primary cardiac diagnosis, type and length of cardiac catheterization, complications (including their time of detection and resolution), and length of hospital stay.

Clinical outcomes

Complications were classified as major, minor, or incidents according to the following criteria:⁶

- *Major complications* included all events leading to one or more of the following: death, life threatening haemodynamic decompensation, the need for surgical or another catheter-based intervention, a significant unanticipated permanent anatomic or functional lesion resulting from the catheterization procedure, such as a cerebral infarct.
- *Minor complications* included unanticipated events, such as arrhythmias or thrombosis of vessels, that were transient and resolved with specific treatment.

- *Incidents* included more trivial adverse events that did not affect the condition of the patient, and that required minimal or no treatment, such as transient fever.

Complications were also categorized as vascular-related, such as arterial or venous thrombosis, or tearing or perforation of vessels; bleeding, such as finding a hematoma at site of insertion of a catheter; arrhythmias; events related to the interventional procedure, such as embolisation of a device; catheter manipulations, such as perforation of vessels or cardiac structures; and miscellaneous. To determine whether or not complications would have been identified prior to discharge of the same day, time intervals from the end of the procedure to detection of complications were noted. Also noted were significant nursing interventions, such as intravenous medication, blood transfusions, or monitoring on the intensive care unit, initiated within 5 hours of the catheterization.

Hypothetical discharge

Patients who originally met the criteria for the planned outpatient strategy were divided into 2 groups:

- Those who could have been discharged the same day, due to the absence of both observed post-catheterization complications and of nursing interventions begun within five hours.
- Those who potentially would have required a post-catheterization overnight stay due to significant complications detected, and/or nursing procedures begun, within the 5-hour hypothetical period of observation prior to discharge. It was our hypothesis that children receiving these interventions would have been too unstable to be sent home five hours after the catheterization.

Estimation of costs

The hypothetical comparison of costs took the perspective of the hospital performing the catheterization, and therefore excluded costs incurred before the hospitalization or after discharge. To estimate the utilization of staff time, nursing and medical personnel determined the amount of time they would expect to spend with patients, based on age and procedure. Personnel costs were then calculated by multiplying the staff utilization time by costs per unit of staff time based on the appropriate figures on salaries plus benefits for nurses and physicians in the year 2000. As physicians were employed by the hospital, the costs for them to perform catheterization procedures, follow patients in hospital, and perform inpatient diagnostic tests were included.

The hospital's information specialist, along with the personnel responsible for patient financial services, at the Swiss children's hospital provided data on standardized direct and indirect daily costs within the hospital. Estimates of the fixed costs in the hospital, taking account of direct as well as indirect or overhead costs, and of variable costs relating to the use of the hospital room and the specific catheterization procedure performed, were obtained from hospital accounting records. Calculation of costs for the catheterization procedures was based on the tax point system for Zurich's Cantonal Health Department. Each procedure within a different department is given a different number of tax points, based on the cost and time required to perform the procedure, as indicated by data from the previous year. This provides a standard by which to compare cost and utilization across different departments within the hospital.

Costs for inpatient stays reflect those of a routine stay lasting for two nights and three days. These include the costs of room and board for three days, appropriate personnel costs, and the costs of supplies, equipment, and room time of the catheterization procedure itself. Costs were truncated at three days, as this is the standard length of stay for catheterization at this Swiss hospital. Costs of subsequent care, such as repeat catheterization procedures following initially unsuccessful interventions, under either the inpatient or outpatient strategy, were excluded from this analysis. The costs of the outpatient strategy were divided into two categories:

- Costs for patients who were clinically stable at five hours after catheterization and could have been discharged same day.
- Costs for patients who had complications within the first five hours, and/or nursing procedures that were started within the 5-hour period of observation, and therefore would have potentially required an overnight stay.

Costs listed under the first category were based on the presumption that admission and discharge occurred on the same day, and included costs of the catheterization, as well as costs for outpatient bed use and nursing care such as feedings and monitoring of vital signs. Excluded were costs associated with the day before and the day after the procedure. Costs for patients in the second category included those of admission the morning of the procedure, cost for the procedure, and costs of the subsequent overnight stay.

We assumed that routine pre-catheterization tests were performed during the admission for both the inpatient and outpatient procedures. Their costs,

therefore, were included in costs of each strategy. Costs of procedures routinely performed in the Swiss hospital, such as overnight electrocardiography monitoring, but not in the American hospital, were not included in either strategy. Costs of testing after catheterization, such as chest X-rays and echocardiograms following certain interventional procedures, routinely performed before discharge at Swiss children's hospital, were included in costs of the inpatient strategy. The American model shifts these costs to the first visit to the clinic made after catheterization. They were excluded, therefore, from all patients under the outpatient strategy, including those with planned same-day discharges converted to overnight stays. These costs might be incurred by facilities other than the hospital where the catheterization was performed.

Estimation of reimbursement

We estimated reimbursement based on the policies used in Switzerland for the year 2000. Reimbursement for cardiac catheterization came in part from the federally funded Invalidenversicherung insurance, which covers children with congenital abnormalities. Other sources include monies from private insurance companies (Krankenkasse), or self-payment. For an inpatient stay, both the Krankenkasse and the Invalidenversicherung pay a set daily rate regardless of the procedure performed. For treatment as an outpatient, however, the Krankenkasse or Invalidenversicherung reimburses at full-itemized cost for all procedures, materials, and equipment. For patients with private insurance and no Invalidenversicherung, we estimated the reimbursement for both inpatient and outpatient stays at full itemized cost.

Analysis

All data were entered into SPSS and Excel for analysis. The 95% confidence intervals were generated using an on-line program.⁷

Eligibility for planned outpatient catheterization

The first goal of our study was to determine the proportion, and 95% confidence intervals, of patients who satisfied the criteria for including their cardiac catheterizations as potential outpatient procedures.

Clinical outcomes

For potential outpatients identified under this goal, we determined the proportion, and 95% confidence intervals, of patients with clinically significant complications, either major or minor, that would not have been identified prior to discharge. We also determined the proportion of patients who had nursing

interventions that would have precluded their discharge on the same day. Evaluating the effectiveness of the catheterization was beyond the scope of this analysis; therefore we did not assess either the accuracy of diagnostic procedures, or the success of interventional catheterizations.

Cost analysis

Costs were expressed in Swiss francs according to their value in the year 2000, using the Swiss consumer price index (www.statistik.admin.ch). Each patient identified under our initial goal had the estimated costs of their actual inpatient stay, and the hypothetical costs of outpatient treatment, based on discharge on either the same day or the next day as described above. We calculated means and standard deviations of the costs per patient according to treatment as an inpatient or outpatient, and of the difference between them, and performed a paired t-test of costs per patient under each strategy. p values < 0.05 were considered statistically significant. For the two strategies, we also compared differences between costs as calculated above, and revenues expected under the current policies for reimbursement in Switzerland.

Due to the hypothetical nature of the study, we could not assess the true clinical consequences, nor the entrained costs of discharging patients under the outpatient strategy, and/or of having them potentially return for management of subsequently identified complications. Instead, we performed a cost-consequence analysis⁵ that described costs and outcomes, but did not combine them to generate true incremental ratios of cost-effectiveness.

Results

Sample

A total of 350 patients underwent cardiac catheterization at the Swiss children's hospital between January 1998 and December 1999. Applying the criteria for inclusion and exclusion, we identified 211 children as possible candidates for treatment as outpatients. Following review of the charts, 28 of these children were eliminated due to their clinical status, emergency catheterizations, or changes in planned procedures during catheterization. Inability to find 4 charts left a total sample of 179 children who potentially could have been treated as outpatients (Table 1). These children account for 51.7% (continuity-corrected 95% confidence interval = 46.3%–57.1%) of the 346 patients with available charts.

Complications

Amongst the children, we encountered (Table 2) 4 major complications (2.2%), 20 minor complications

Table 1. Frequencies and percentages of selected characteristics of study sample.

| Characteristic | Number of cases (n = 179) | Percent |
|---|---------------------------|---------|
| Gender | | |
| Male | 96 | 54 |
| Female | 83 | 46 |
| Age group | | |
| 0-<2 Months | 3 | 2 |
| 2-<4 Months | 3 | 2 |
| 4-<6 Months | 5 | 3 |
| 6-<1 Year | 27 | 15 |
| 1-<4 Years | 42 | 23 |
| 4-<10 Years | 52 | 29 |
| 10 Years and Older | 47 | 26 |
| Insurance type | | |
| Invalidenversicherung | 160 | 89 |
| General Insurance | 14 | 7 |
| Private Self Pay | 1 | 1 |
| Social Help | 1 | 1 |
| Invalidenversicherung and General Insurance | 3 | 2 |
| Catheterization procedure | | |
| Diagnostic (Anatomical) | 92 | 51 |
| Diagnostic (Electrophysiology) | 2 | 1 |
| Diagnostic (Anatomical and Electrophysiology) | 8 | 4 |
| Pre-operative Coil Placement | 9 | 5 |
| Other (Anatomical Interventional) | 24 | 13 |
| Interventional Electrophysiology | 44 | 25 |

(11.2%) and 9 incidents (5%). The complications of most concern for this study were those first noted five hours or more subsequent to catheterization, as they might have occurred after discharge on the same day.

Of the four major complications, two were discovered after the 5-hour hypothetical period of observation. In one case, a 4 year 9 month old child with an isolated patent arterial duct, the complication followed implantation of a Bard PDA Umbrella Device. Chest X-ray performed the day after catheterization, as is routine following all cardiac device implantations in this Swiss hospital, showed movement of the umbrella, producing stenosis of the left pulmonary artery. Repeat catheterization failed to reposition the device, necessitating surgery for its removal and for closure of the duct.

The second major complication detected after 5 hours occurred in a 12 year 11 month old child with a previous Fontan operation for complex congenital cardiac disease. Scheduled diagnostic catheterization, and diagnostic electrophysiology, revealed a persistent left superior caval vein. Closure was attempted using a coil. Routine chest X-ray the following day showed movement of the coil, as well as a residual shunt. Successful re-catheterization to place more

coils to close the residual shunt, as well as to prevent further movement of the existing coils, was performed a day later.

Among the 20 minor complications, only one was discovered after five hours. A right atrial thrombus was discovered on routine echocardiography following radio frequency catheter ablation. Intravenous heparin dissolved the clot. Two incidents, a "transitory migraine" headache and a fever, also occurred after five hours. Neither condition required treatment, and both patients were discharged on schedule.

In addition to the complications, 41 patients (23%) had significant nursing interventions initiated within the 5-hour hypothetical period of observation prior to discharge (Table 3). It was hypothesized that these children would be too unstable to go home after five hours, and therefore would have needed an overnight stay. One of the three patients with a "significant" complication discovered after 5 hours, namely the child with attempted placement of coils in the persistent left superior caval vein, was also included in this group. This child received intravenous pain and anti-emetic medication 8 hours after the catheterization. The other two patients with significant complications were stable at five hours, and therefore could have been sent home on the same day. Thus, among the 179 patients, there were three "significant" complications, two major and one minor (1.7%; continuity-corrected 95% confidence interval = 0.4–5.2%) that may have gone undetected prior to discharge.

Costs and reimbursement

Costs

Calculated costs are shown in Table 4. Of note is the higher cost of interventional procedures, which reflects the longer procedural times and prices of the devices. For interventional as well as purely diagnostic procedures, mean costs for discharge on the same day were less than those for discharge on the next day. However, in the category of "all patients", a higher proportion of patients stable enough for discharge on the same day had interventional procedures. Therefore, mean costs for the group discharged on the same day exceeded those of patients kept overnight by nearly 500 francs. Costs of routine post-catheterization imaging tests were included for inpatients, and excluded for those undergoing the outpatient strategy, including patients kept overnight, for reasons previously stated. The overall mean cost of the inpatient strategy was 10,946 Swiss francs ($\pm 2,307$ Swiss francs) per patient, as compared to 9,790 Swiss francs ($\pm 2,050$ Swiss francs) for the hypothetical outpatient strategy in the same patients. The difference is 1,156 Swiss francs (± 410 Swiss francs); $p < 0.001$ by paired t-test.

Table 2. Frequency and type of complications discovered before and after 5 hours.

| | Number of complications discovered before 5 hours | | | Number of complications discovered after 5 hours | | |
|--|---|-------|----------|--|-------|----------|
| | Major | Minor | Incident | Major | Minor | Incident |
| Post-catheterization bleeding at catheter insertion site | | | | | | |
| ● 0-<1 Hour post cath | | 5 | | | | |
| ● 1-2 Hour post cath | | 3 | | | | |
| Arrhythmias | | | | | | |
| ● Recurrent SVT 2 Hour following radio frequency cath ablation | | | 1 | | | |
| ● Transient ST changes during catheterization | | | 4 | | | |
| ● Arrhythmia requiring pacing | | 1 | | | | |
| ● Bradycardia leading to cardiac arrest | 1 | | | | | |
| Vascular events | | | | | | |
| ● Arterial thrombosis requiring intravenous heparin | | 5 | | | | |
| ● Atrial thrombus requiring intravenous heparin | | | | | 1 | |
| ● Coronary sinus diverticle requiring IV heparin | | 1 | | | | |
| Movement of implanted device | | | | | | |
| ● PDA Umbrella | | 1 | | 1 | | |
| ● Coil | | 1 | | 1 | | |
| Other | | | | | | |
| ● Moderate hypoxic episode | | 2 | | | | |
| ● Catheter/Guidewire complication | | | 2 | | | |
| ● Fever | | | | | | 1 |
| ● Transitory migraine-type symptom | | | | | | 1 |
| ● Technical problem | 1 | | | | | |
| Total | 2 | 19 | 7 | 2 | 1 | 2 |

Table 3. Nursing interventions begun within 5 hours of conclusion of heart catheterization.

| Intervention | Number of interventions* |
|--|--------------------------|
| Oxygen | 27 |
| Intravenous pain or anti-emetic medication | 5 |
| Intravenous heparin | 5 |
| Lab work due to post-op fever | 5 |
| Blood transfusion (Packed Red Blood Cells) | 2 |
| Intensive care unit monitoring | 2 |

*These 46 procedures were performed on a total of 41 patients (23% of 179)

Reimbursement and net revenue

For each strategy, net revenues were the difference between expected reimbursement and total costs. Reimbursement reflected the mix of insurance types. For the inpatient strategy, subtracting reimbursements of 426,098 Swiss francs from total aggregate inpatient costs of 1,959,287 Swiss francs produced a net aggregate revenue deficit of 1,533,189 Swiss francs, or 8565 Swiss francs per patient.

The reimbursement for the 138 patients who had no contraindication to discharge on the same day would have been at the full itemized estimated cost of the procedure, thereby producing no net revenue gain

or deficit. The patients who had nursing procedures begun within the period of observation would have been kept overnight, thus converting their encounters into inpatient stays. There would have been reimbursement on a per diem basis rather than with the itemized reimbursement of an outpatient stay. With reimbursement adjustments, total reimbursement for the outpatient strategy comes to 1,437,994, Swiss francs, or an average of 8033 Swiss francs per patient. Subtracting this outpatient reimbursement figure from the total aggregate cost of the outpatient strategy (1,366,590 + 385,818 Swiss francs) gives a net revenue deficit of 314,414 Swiss francs, or an average of 1756 Swiss francs per patient for the outpatient strategy. This deficit reflects the difference between cost and reimbursement for those planned outpatients who would have incurred overnight stays. This mean deficit is approximately one-fifth of the mean deficit incurred under the inpatient strategy.

Discussion

Sample

We found that approximately half of the children undergoing cardiac catheterization during the prescribed time period met the criteria for inclusion

Table 4. Mean costs per patient (in year 2000 Swiss francs*).

| Procedure group | Outpatient strategy | | | | | | | | | | | |
|---|---------------------|-----------|---|-------------------------------------|-----------|---|---|-----------|---|--------------|-----------|---|
| | Inpatient strategy | | | Could have been discharged same day | | | Would have been kept overnight for complications or nursing interventions | | | All patients | | |
| | N | Mean cost | Mean cost as a % reduction of inpatient strategy cost | N | Mean cost | Mean cost as a % reduction of inpatient strategy cost | N | Mean cost | Mean cost as a % reduction of inpatient strategy cost | N | Mean cost | Mean cost as a % reduction of inpatient strategy cost |
| Purely diagnostic procedures (including electrophysiology procedures) | 102 | 9,080 | 11.2 | 69 | 8,062 | 11.2 | 33 | 8,482 | 6.6 | 102 | 8,198 | 9.7 |
| Interventional procedures (\pm diagnostic procedures) | 77 | 13,417 | 12.5 | 69 | 11,743 | 12.5 | 8 | 13,241 | 1.3 | 77 | 11,899 | 11.3 |
| All procedures | 179 | 10,946 | 9.5 | 138 | 9,903 | 9.5 | 41 | 9,410 | 14.0 | 179 | 9,790 | 10.6 |

*1.688 Swiss francs per 1 United States dollar per CIA World Factbook (www.odci.gov)

for treatment as an outpatient. Surprisingly, 93% of the eligible patients were over the age of 6 months, with 78% over the age of 1 year, and 55% over the age of 4 years. Since half of the catheterizations in this sample were anatomical diagnostic catheterizations, a larger proportion of children under 1 year would have been expected. The high percentage of older children may reflect:

- The selection criteria for outpatients which excluded any clinically unstable children, who are typically younger patients.
- The large proportion (25%) of cases that were interventional electrophysiology procedures most of which were performed on children over the age of 4.
- The number of coil closures performed as a part of multi-stage interventions in older children who had already undergone their primary surgical procedures.

Complications

The safety of cardiac catheterization as an outpatient is based on the premise that any significant complication will occur before discharge, and thus be detected and treated during the period of hospitalization. The majority of complications did indeed happen before the appointed time of discharge time. The surprising finding of our study is that three significant complications were detected after the 5-hour period of observation. The overnight hospitalization

period itself did not contribute to the detection of these complications. As these children were asymptomatic, their complications were detected solely by chest X-rays and echocardiograms routinely performed following implantation of devices and radio frequency catheter ablations.

An unexpected finding was the number of children still having significant nursing procedures at the end of the 5-hour period of observation. The most plausible explanation is that nursing care was oriented towards a planned overnight stay, not the hypothetical outpatient procedure we described. The use of general anesthesia, which is known to prolong the phase of recovery, could provide another possible reason.

Costs

Our data indicate that the outpatient strategy might only reduce costs by about one-tenth, due to the fact that most of the costs were those of the catheterization procedure itself, and because almost one-quarter of patients still required an overnight stay. The current Swiss policies for reimbursement, however, magnify the financial implications of converting catheterization to a planned outpatient procedure. The Swiss system reimburses for inpatient stays at daily rates that are lower than real costs, while outpatient reimbursement is at a level equal to itemized costs. As long as this occurs, there will be large differences between the net revenues realized for inpatient versus outpatient procedures. While net revenue for both strategies showed deficits, if one could eliminate the significant late nursing procedures that

necessitate an overnight stay, increased reimbursement for the outpatient strategy would greatly reduce the deficit. The fact this financial incentive has not led to outpatient catheterization might reflect the absence of current published data on the safety or cost implications of outpatient procedures.

Study limitations

The main limitation of our study was its hypothetical nature. As no catheterizations were performed with discharge on the same day in this Swiss children's hospital, we relied on modeling rather than observation to postulate the costs and outcomes of the procedure performed on an outpatient basis. We could not, therefore, calculate true ratios of cost-effectiveness for the incremental costs for premature discharge averted by using an inpatient rather than an outpatient strategy.

This retrospective study was based on reviews of charts, requiring investigators to make inferences regarding missing information, such as motivations surrounding post catheterization medication and its route of administration. As estimates of the real incurred costs were not available, we applied standardized unit costs per bed-day, and so on, to observed and hypothetical scenarios of observed uses of resources. This suppresses the variability in estimates of true costs,⁸ perhaps unduly increasing the statistical significance of our t-test results. Our small sample size was also a limitation. As Lee et al.⁹ point out in their study of adults catheterized as outpatients, low rates of morbidity and mortality require large samples for detection.

Our study does not address the issue of shifting care, and associated costs, that would result from the move from an inpatient to an outpatient strategy. For example, all pre-catheterization laboratory tests now performed upon admission the day before the catheterization would need to be performed the day of the catheterization, or on the final clinic visit before the catheterization. Similarly, any examinations subsequent to catheterization, such as X-rays or echocardiograms, would need to be performed the same day before the child is discharged, or at the next clinic visit. These changes may necessitate a shift in the organization and personnel. It is not necessarily true that this shift would avoid all costs associated with bed and other resource use averted by shifting to an outpatient strategy. Finally, our clinical outcomes, along with estimates of costs and reimbursement, were based on the Swiss healthcare system. Our results would be of interest in other settings where inpatient cardiac catheterization is common. The generalizability of our results to other settings is unknown.

Study implications

The positive effects of performing procedures on children as outpatients are well documented,^{10,11} Additional benefits this change in venue may bring to children and their families could include reducing exposure to nosocomial infections. It would also increase convenience, and provide the opportunity for convalescence to occur in the familiar atmosphere of the patient's home.

The few "significant" complications discovered after the hypothetical period of discharge were found through routine follow up imaging, rather than hospitalization itself. It would be of interest to investigate time intervals between catheterization and routine follow-up imaging in other pediatric centers, and to note types of complications discovered at different times. Our results might argue for planned imaging before discharge, or within some specified post-discharge interval, especially following certain interventional procedures. The frequency with which nursing procedures were performed after the 5-hour period of observation prior to discharge calls into question the degree to which overnight stays can be eliminated. The degree to which use of select anesthetic agents, short stay facilities, and staff experienced in outpatient care would significantly change the numbers of late nursing procedures remains to be seen.

It is unclear as to what degree the modest cost reductions seen would encourage outpatient catheterization. They must be weighed against the risk of discharging patients without imaging or observation that might detect significant complications. The financial attractiveness of outpatient catheterization arises less from cost reductions than from potentially narrowing the gap between costs and revenues associated with the current reimbursement structure of the Swiss health care system. Our results, related to both clinical and financial aspects, indicate that outpatient catheterization merits prospective evaluation in the Swiss health care system. In the absence of other studies with which to compare our demographic, clinical or cost analysis findings, we hope our results will encourage others to address this issue.

Acknowledgements

The authors thank Collette Fearneyhough, ARNP of Seattle Children's Hospital and Regional Medical Center, for providing the description of their outpatient catheterization criterions. We also thank Dr. Urs Bauersfeld, Head of Cardiology and the staff of nurses at University Children's Hospital (Zurich, Switzerland), for providing detailed information on their current paediatric cardiac catheterization care, and the Medical Records personnel for their invaluable

help in locating the patient records needed for this study. The results of this study do not necessarily reflect the opinions of the staff at Seattle Children's Hospital and Regional Medical Center or University Children's Hospital in Zurich.

References

1. Pihkala J, Nykanen D, Freedom RM, Benson LN. Interventional Cardiac Catheterization. *Pediatr Clin North Am* 1999; 46: 441–460.
2. Williams SJ, Torrens PR. *Introduction to Health Services*, 5th edn. Delmar Publishers, Albany, NY, 1999.
3. Powell CB, Moller JH. Outcomes research using a voluntary generic registry. *Prog Pediatr Cardiol* 1997; 7: 87–90.
4. Waldman JD, Young TS, Pappelbaum SJ, Turner SW, Kirkpatrick SE, George L. Pediatric cardiac catheterization with same-day discharge. *Am J Cardiol* 1982; 50: 800–803.
5. Mauskopf JA, Paul JE, Grant DM, Stergachis A. The role of cost-consequence analysis in healthcare decision making. *Pharmacoeconomics* 1998; 13: 277–288.
6. Vitiello R, McCrindle BW, Nykanen D, Freedom RM, Benson LN. Complications associated with pediatric cardiac catheterization. *J Am Coll Cardiol* 1998; 32: 1433–1440.
7. <http://faculty.vassar.edu/lowry/prop1.html>; based on: Newcombe R. Two-sided confidence intervals for the single proportion: comparison of seven methods. *Stats in Medicine* 1998; 17: 857–872.
8. Rittenhouse B, Dulisse B, Stinnett A. At what price significance? The effect of price estimates on statistical inference in economic evaluation. *H Econ* 1999; 8: 213–219.
9. Lee JC, Bengtson JR, Lipscomb J, et al. Feasibility and cost-saving potential of outpatient cardiac catheterization. *J Am Coll Cardiol* 1990; 15: 378–384.
10. Gerdes JE. An ambulatory approach to outpatient pediatric cardiac catheterization. *J Post Anesth Nurs* 1990; 6: 407–410.
11. Scaife JM, Campbell I. A comparison of the outcome of day care and inpatient treatment of pediatric surgical cases. *J Child Psychol Psychiatry* 1988; 2: 185–198.