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ORIGINAL RESEARCH

CONGENITAL HEART DISEASE

How Good Are Cardiologists at Predicting Major Adverse Events in Fontan Patients?

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ABSTRACT

BACKGROUND It is unknown how well cardiologists predict which Fontan patients are at risk for major adverse events (MAEs).

OBJECTIVES The purpose of this study was to examine the accuracy of cardiologists' ability to identify the "good Fontan" patient, free from MAE within the following year, and compare that predicted risk cohort to patients who experienced MAE.

METHODS This prospective, multicenter study included patients ≥10 years with lateral tunnel or extracardiac Fontan. The cardiologist was asked the yes/no "surprise" question: would you be surprised if your patient has a MAE in the next year? After 12 months, the cardiologist was surveyed to assess MAE. Agreement between cardiologist predictions of MAE and observed MAE was determined using the simple kappa coefficient. Multivariable generalized linear mixed effects models were performed to identify factors associated with MAE.

RESULTS Overall, 146 patients were enrolled, and 99/146 (68%) patients w`ere predicted to be a "good Fontan." After 12 months, 17 (12%) experienced a MAE. The simple kappa coefficient of cardiologists' prediction was 0.17 (95% CI: 0.02-0.32), suggesting prediction of MAE was 17% better than random chance. In the multivariable cardiologist-predicted MAE (N = 47) model, diuretic/beta-blocker use ($P \leq 0.001$) and systolic dysfunction ($P = 0.005$) were associated with MAE. In the observed multivariable MAE (N = 17) model, prior unplanned cardiac admission ($P = 0.006$), diuretic/beta-blocker use ($P = 0.028$), and ≥moderate atrioventricular valve regurgitation ($P = 0.049$) were associated with MAE.

CONCLUSIONS Cardiologists are marginally able to predict which Fontan patients are at risk for MAE over a year. There was overlap between factors associated with a cardiologist's prediction of risk and observed MAE, namely the use of diuretic/beta-blocker. (JACC Adv 2024;3:100736) © 2024 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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ABBREVIATIONS AND ACRONYMS

AV = atrioventricular

IRB = institutional review board

MAE = major adverse event

MVA = multivariable analysis

Individuals who have a functionally univentricular heart are at risk for adverse outcomes in a bimodal distribution: the first phase is around the time of the initial surgeries, followed by a period of quiescence, and then increased morbidity and mortality in late adolescence into adulthood.[1,2] This period of transition poses challenges for the patient, families, and physicians, who may be surprised by a sudden adverse event after a period of stability. It is the outpatient cardiologist who, through the lens of longitudinal care, has the best vantage to surveil the patient, predict levels of risk, and prepare the patient/families for these potential events. What is not clear is how good the cardiologist is at predicting which patients are doing well (the "good Fontan") vs those at higher risk for major adverse events (MAEs).

The ability to risk stratify is critical. This may help guide the cardiologist in the counseling provided to patients and families regarding serious risks and potential complications. Timely identification of cardiac dysfunction, arrhythmias, and other risk factors enables earlier medical or surgical interventions to address these issues and potentially prevent unexpected adverse events. In addition, risk stratification helps to determine the need for frequency of follow-up and testing, which may be variable.[3]

The surprise question, namely, "Would you be surprised if the patient died within the next year?" has been used in a variety of adult populations to predict mortality risk. In selected populations, the "surprise" question has been found to be effective in identifying those patients with a high risk of early mortality.[4,5] In this study, we sought to examine how effectively a modified "surprise" question focused on risk of morbidity and mortality, when posed to congenital cardiologists, would distinguish the "good Fontan" from those individuals who experienced MAE. Additionally, we examined clinical characteristics associated with physician prediction of MAE vs clinical characteristics associated with patients experiencing MAE.

METHODS

We performed a prospective observational multi-institutional study with enrollment across 9 New England congenital heart centers of various sizes. Patient subjects were approached between March 2018 and September 2019 by study personnel at each site and enrolled after appropriate informed consent. Subsequently, the attending cardiologist was also enrolled in the study. Study approval was obtained by the institutional review board (IRB) at Boston Children's Hospital, which acted as the primary IRB. All other centers entered into a reliance agreement with the primary IRB or submitted their own IRB application. Included patient subjects were ≥10 years of age and had a history of prior Fontan operation, either lateral tunnel or extracardiac Fontan. Exclusion criteria included prior Fontan conversion or revision, history of evaluation or listing for heart transplant, or pregnancy.

MAEs were predefined as any of the following: 1) all-cause mortality; 2) evaluation or listing for cardiac transplant following enrollment; 3) unplanned cardiac hospitalization; 4) unplanned cardiac intervention (excluding fenestration device closure or device battery replacement); 5) clinically significant atrial arrhythmia (atrial fibrillation, flutter, or supraventricular tachycardia) requiring cardioversion, inpatient admission, new antiarrhythmic medication, or ablation; 6) sustained ventricular tachycardia requiring intervention or ≥30 seconds on Holter or other monitoring; 7) development of significant new or worsening ascites; 8) development of new protein-losing enteropathy and/or plastic bronchitis; 9) placement of a new pacemaker or defibrillator; or 10) new intracardiac thrombus formation or stroke.

At the time of enrollment and after reviewing our criteria for any MAE, the attending cardiologist answered the modified "surprise" question: "Would you be surprised if your patient has a MAE in the next year?" Answers were recorded as yes/no and were made at the sole discretion of the attending cardiologist based on any available data and knowledge of the patient.

Our primary hypothesis was as follows: the answer of "yes" to the "surprise" question by an attending cardiologist caring for a patient with Fontan identifies patients who are at a low risk (the "good Fontan") for mortality or significant morbidity in the subsequent 12 months. The secondary hypothesis was that the clinical characteristics associated with physician prediction of MAE would be the same as those associated with actual MAE.

At the time of enrollment, clinical data were collected from the medical records of participating institutions. This included cardiac diagnosis, dominant ventricular morphology, genetic diagnoses, surgical history, history of prior cardiac complications including unplanned cardiac hospitalization in prior year, electrophysiology history, comorbid conditions including psychiatric diagnoses, current medication usage, most recent echocardiographic data, recent laboratory data including renal function, liver function, and complete blood count (within 1 year).

Echocardiographic data were collected from the most recent report and were dichotomized for statistical purposes as follows: ≥ moderate atrioventricular (AV) valve regurgitation vs none to mild, ≥ moderate semilunar valve insufficiency vs none to mild, and ≥ moderate systolic dysfunction vs normal to mild dysfunction. At baseline, the patient was surveyed about frequency of baseline "vigorous" physical activity. At the end of the 12-month period, the attending cardiologist was surveyed to assess for any MAE that occurred in the last year for their enrolled patient. Events were nonexclusionary, so some patients had multiple events within the 12 months, and time to event was recorded.

STATISTICAL METHODS. Clinical characteristics were described using counts (percentages). To examine agreement between predictions of MAE and observed MAE, we calculated the simple Kappa coefficient, which quantifies how much the observed agreement exceeds agreement by chance alone. We created unadjusted and adjusted generalized linear mixed effects models (link = logit) in order to examine factors associated with the cardiologist's prediction of MAE at baseline, as well as models to examine factors associated with the observed MAE. A random intercept for a cardiologist was included to account for the clustering of patients within a provider. Multivariable models were constructed by using any predictors that had P values <0.10 in the unadjusted models. For the final multivariable models, to avoid multicollinearity, we created a combined predictor of use of beta-blocker or diuretic as there was substantial overlap in the variables. Results from the models were summarized using odds ratios (ORs), and statistical hypotheses were conducted at the 2-sided alpha of 0.05. Data were analyzed using SAS 9.4.

RESULTS

A total of 146 patients (mean age at enrollment: 21.2 ± 7.7 years) and 40 cardiologists participated in the study. The physicians enrolled were quite experienced and had a mean practice of 21 years in cardiology postfellowship (±12 years).

For Fontan patients, there was a relative balance in terms of dominant systemic ventricular morphology: left 49%, right 47%, and indeterminate 4%. The most common cardiac diagnoses were hypoplastic left heart syndrome 42 (32%) and tricuspid atresia (18%). Table 1 provides baseline details about the overall population.

Most of the 146 patients enrolled required neonatal surgery (n = 105, 72%), which often involved aortic arch intervention (n = 55, 38%). Lateral tunnel was more common than extracardiac Fontan in this population (n = 99, 68% vs n = 47, 32%). All patients had normal renal function at baseline. In terms of the surprise question asked at the time of enrollment, the attending cardiologist predicted 99 of 146 (68%) patients to be "good Fontan," whereas 47/146 (32%) were thought to be "at risk" of a MAE.

TABLE 1 Baseline Characteristics of the Study Population (N = 146)

Mean age (y)	21.2 ± 7.7
Dominant ventricular morphology	
Left	72 (49%)
Right	68 (47%)
Indeterminate	6 (4%)
Fontan type	
Lateral tunnel	99 (68%)
Extracardiac	47 (32%)
Heterotaxy diagnosis	
Yes	22 (15%)
No	124 (85%)
Known genetic diagnosis	
Yes	8 (5%)
No	138 (95%)
NYHA functional class at enrollment	
I	74 (51%)
II	29 (20%)
III	3 (2%)
Unknown	40 (27%)
Systolic function by echocardiogram	
Normal	99 (68%)
Mildly depressed	34 (23%)
Moderately depressed	8 (5%)
Severely depressed	3 (2%)
Missing	2 (1%)
AV valve regurgitation by echocardiogram	
None/trivial regurgitation	102 (70%)
Mild regurgitation	21 (14%)
Moderate regurgitation	5 (4%)
Severe regurgitation	0 (0%)
Missing	18 (12%)

Values are mean ± SD or n (%).
AV = atrioventricular.

ADVERSE EVENTS. Over the 12 months following enrollment, 17 (12%) patients experienced a MAE (Table 2). One adverse event was reported for 9 patients (53%), while 7 patients (37%) had 2 events within the year and 1 patient (6%) had 5 events within 1 year of enrollment (Table 2). Four of the patients, comprising 24% of the patients who experienced MAE, had a diagnosis of heterotaxy syndrome. One participant had neurofibromatosis type 1 and another had a heterozygous mutation in the DNAH5 gene. None of the patients died during the study follow-up.

TABLE 2 Major Adverse Events (N = 17)

Number of adverse events/patient[a]	
1	9 (53%)
2	7 (37%)
5	1 (6%)
Adverse event type (predefined):	
Evaluation/listing for heart transplant	3
Intracardiac thrombus/stroke	3
Clinically significant atrial arrhythmia	5
Pacemaker/defibrillator placement	3
Unplanned cardiac hospitalization	9
Unplanned cardiac intervention	3
Significant/worsening ascites	1
New protein-losing enteropathy and/or plastic bronchitis	1
Death	0
Provider prediction of risk (surprise question)	
Good Fontan	7 (41%)
At Risk Fontan	10 (59%)

Values are n (%) or n. [a]Some participants with >1 event reported within 12 months.

The most common adverse event was unplanned cardiac hospitalization, which occurred in 9 individuals. These unplanned cardiac hospitalizations occurred for a variety of reasons: hemoptysis (n = 2), supra-ventricular arrhythmia requiring admission (n = 2), heart failure, device lead failure, protein losing enteropathy, endocarditis, and complications related to Fontan liver disease (jaundice).

HOW GOOD ARE CARDIOLOGISTS AT PREDICTING A "GOOD FONTAN"? Of the 17 patients who experienced MAE, 10 (59%) were predicted to be "higher risk," whereas 7 (41%) were predicted to be "good Fontans." Of the remaining 129 patients who did not experience MAE, 92 (71%) were predicted to be "good Fontans," while 37 (29%) were deemed "higher risk." The simple Kappa coefficient was 0.17 (95% CI: 0.02-0.32), which suggested that the cardiologist's ability to predict events was 17% better than random chance alone (Central Illustration).

UNIVARIABLE AND MULTIVARIABLE MODELS. Unadjusted associations with cardiologists' prediction of MAE included the patient's age, NYHA functional class, prior adverse events, prior fenestration closure, systolic dysfunction, and beta-blocker or diuretic usage (Table 3). In the final adjusted model, cardiologist prediction of MAE was associated with diuretic or beta-blocker use (OR: 5.7, $P \leq 0.001$) and systolic dysfunction (OR: 3.3, $P = 0.005$) (Table 4).

Unadjusted predictors of observed any MAE included NYHA functional class, prior unplanned cardiac admission, ≥ moderate AV valve regurgitation, ≥ moderate systolic dysfunction, and diuretic use (Table 3). In the multivariable model, there were 3 predictors of MAE: prior unplanned cardiac admission (OR: 11.6, $P = 0.006$), diuretic or beta-blocker use (OR: 4.6, $P = 0.028$), and ≥ moderate AV valve regurgitation (OR: 8.9, $P = 0.049$) (Table 4).

DISCUSSION

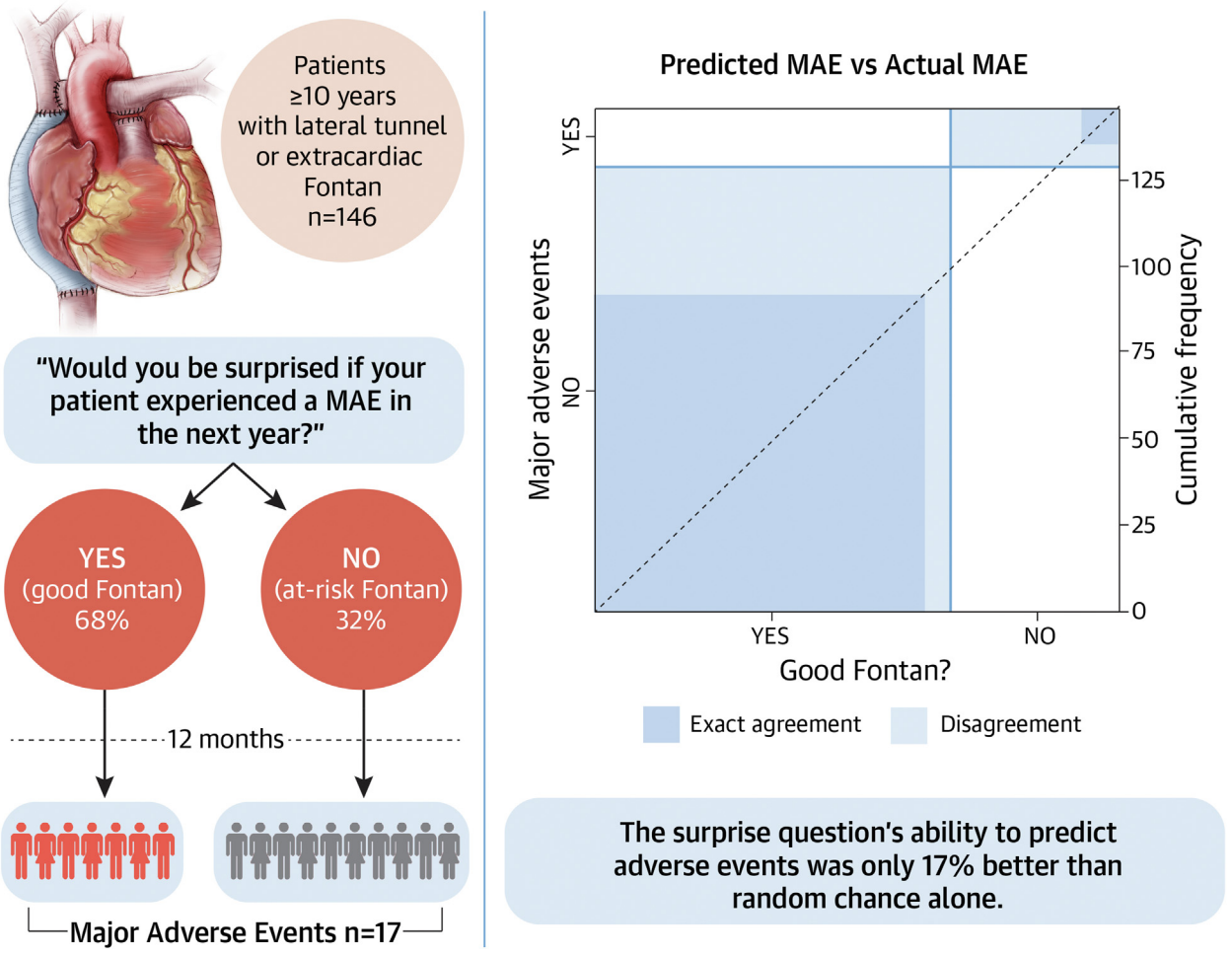
Some cardiologists refer to the third stage of surgical repair for the patient with a functionally univentricular heart as the Fontan "palliation," underlying the concern that post-Fontan patients are at risk of increased morbidities and mortality with advancing age. Yet, for those who do well after the initial surgeries, there is often an extended period of stability. Thus, the ability of the cardiologist to predict when patients are at risk of complications is of paramount importance.

Our study has shown for the first time that attending cardiologists are only marginally able to predict which of these outpatient individuals with Fontan are at risk for MAE over the next 12 months. In fact, cardiologists were only 17% better than chance alone at predicting who would have an event.

In examining the 7 individuals who were predicted by their cardiologist to be a "good Fontan" at low risk for MAE yet experienced events, it is not surprising that many of the events were idiosyncratic and difficult to predict. Two patients had supraventricular tachycardia, which required admission, and 1 had a new pacemaker for sinus node dysfunction. One patient experienced hemoptysis, though review showed that patient—although considered low-risk—was NYHA functional class II and had a prior admission for hemoptysis. Two patients, both of whom were previously on aspirin monotherapy for thrombus prophylaxis, had new thrombi develop (1 intracardiac and 1 stroke). Finally, 1 patient thought to be low-risk was admitted for heart failure. That individual was older at enrollment and had stable, mildly depressed ejection fraction, but progressed in symptoms and required unplanned admission for heart failure optimization.

While little congenital data to date has been focused on the complex patient-family-physician interactions surrounding life-threating illness for heart disease, we can learn some trends from the literature surrounding other chronic pediatric conditions. For example, parents of children with cancer rated their care as superior when they were provided clear information about what to expect in advanced care discussions.[6] Another study found that overall parent satisfaction was meaningfully associated with the completeness of information provided about

CENTRAL ILLUSTRATION How Good Are Cardiologists at Predicting Who Is the "Good Fontan" Patient?



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The darker shaded-blue areas represent "exact agreement" where both predicted and actual outcomes are the same; the lighter shaded-blue areas indicate where there was disagreement. The surprise question's ability to predict adverse events was only 17% better than random chance alone.

life-threatening diagnosis and prognosis.[7] For the outpatient cardiologist who has a longitudinal relationship with the patient and family, navigating conversations regarding advanced care discussion and the timing of such discussion is quite a challenge. This challenge may be reflected in the lack of consistent management practice and variable follow-up and testing.[8] Cardiologists typically collect a good deal of data with regular echocardiograms, electrocardiograms, and laboratory evaluation, but the ability to use that data to predict which patients are at risk remains challenging. In a survey of 56 New England congenital cardiologists, surveillance and screening were less frequent in patients they considered low-risk compared to high-risk.[9]

In the adult literature, the surprise question (would you be surprised if the patient died in a certain period of time?) has been suggested as 1 way to identify high-risk patients. In 1 Japanese study of over 2,000 oncology patients, the surprise question had a 90% or greater sensitivity to identify 30-day mortality.[5] Another study of adult primary physicians who were managing high-risk outpatients with chronic illness found that the surprise question was

TABLE 3 Unadjusted Associations for Cardiologist Prediction and Observed MAE Within 12 Months

	Cardiologist Prediction of MAE		Observed MAE Within 12 Months	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Age (y) at enrollment, (quartiles) 4 vs 1	3.1 (1.1-8.7)	0.040	1.2 (0.3-4.3)	0.40
Year of birth (per year inc, eg, younger)	0.94 (0.89-0.98)	0.020	0.97 (0.91-1.03)	0.27
NYHA functional class (II/III vs I)	3.9 (1.4-11.1)	0.010	5.4 (1.2-24.1)	0.026
Vent morphology, R vs L	1.72 (0.80-3.6)	0.15	1.9 (0.64-5.6)	0.24
Heterotaxy	1.43 (0.55-3.8)	0.44	1.8 (0.53-6.3)	0.34
Known genetic diagnosis	2.25 (0.50-10.1)	0.28	2.6 (0.50-14.6)	0.26
Vigorous physical activity (frequent vs none)	2.64 (0.55-12.7)	0.79	0.65 (0.05-8.3)	0.59
Number of cardiac surg (>3 vs ≤3)	2.3 (0.84-6.3)	0.10	0.79 (0.16-3.8)	0.76
Arch surgery	0.75 (0.34-1.7)	0.49	0.64 (0.21-2.0)	0.44
Neonatal cardiac surgery	0.66 (0.30-1.5)	0.32	0.42 (0.14-1.2)	0.11
Age at Fontan completion (per mo inc)	1.01 (0.99-1.0)	0.090	1.01 (0.99-1.02)	0.065
Fontan fenestration	0.89 (0.38-2.1)	0.81	1.2 (0.36-4.1)	0.74
Fontan type (EC vs LT)	1.31 (0.59-2.9)	0.50	0.60 (0.20-2.1)	0.44
History of atrial fibrillation/flutter	3.8 (1.5-10.0)	0.006	1.2 (0.31-4.5)	0.83
History of PPM/ICD	3.3 (1.3-8.5)	0.016	2.5 (0.76-8.0)	0.13
History of stroke/thrombus	1.6 (0.59-4.2)	0.36	2.0 (0.56-6.8)	0.29
Prior unplanned cardiac admission	3.7 (0.79-18.2)	0.096	20.2 (4.1-98.8)	<0.001
Fenestration closure (yes vs no)	0.20 (0.06-0.73)	0.015	0.90 (0.23-3.4)	0.87
Fontan pathway intervention	0.91 (0.40-2.1)	0.82	1.1 (0.32-3.1)	0.99
AVV regurgitation: moderate vs none/trivial	3.8 (1.2-12.6)	0.08	17.1 (2.9-99.2)	0.006
Semilunar regurgitation: moderate vs none/trivial	3.2 (0.5-21.2)	0.37	N/A[a]	N/A[a]
Systolic function (Mod dysfunction vs none/mild)	4.8 (2.1-10.0)	<0.001	3.7 (1.3-10.7)	0.015
ACE/ARB	1.0 (0.5-2.3)	0.97	0.64 (0.22-1.8)	0.39
Anticoagulant/antiplatelet	2.1 (0.2-20.5)	0.53	0.53 (0.05-5.2)	0.58
Beta-blocker	5.4 (2.1-14.1)	<0.001	2.7 (0.89-8.3)	0.078
Diuretic	7.64 (2.9-20.1)	<0.001	7.7 (2.6-23.1)	<0.001
Psych/anxiety med	0.98 (0.40-2.6)	0.97	1.1 (0.27-4.0)	0.94
AED	0.51 (0.05-5.0)	0.57	N/A[a]	N/A[a]
ALT	1.1 (0.50-2.4)	0.88	1.3 (0.43-3.8)	0.63
AST	1.3 (0.55-2.9)	0.57	1.3 (0.41-3.8)	0.68
GGT	2.3 (0.63-8.2)	0.20	2.4 (0.28-22.1)	0.41
HCT (quartiles, 4 [high] vs 1 [low])	0.93 (0.29-3.0)	0.93	0.34 (0.06-2.0)	0.57

[a]Not estimable due to zero count of adverse events.

ACE = angiotensin-converting enzyme; AED = antiepileptic drug; ALT = alanine transferase; ARB = angiotensin II receptor blocker; AST = aspartate transferase; AVV = atrioventricular valve; EC = extracardiac; GGT = gamma-glutamyl transferase; HCT = hematocrit; ICD = implantable cardioverter-defibrillator; LT = lateral tunnel; N/A = not applicable; PPM = permanent pacemaker.

"strongly and significantly associated with 1-year mortality, and this effect was noted over and above known predictors such as age and comorbidities."[4] In our current study we hypothesized that a modified surprise question, designed to capture potential Fontan complications, might clarify which Fontan outpatients were at highest risk of complications over the subsequent year. The marginal performance of this question to predict MAE suggests that, as a community, we have further work to do to understand who is indeed a high-risk patient.

To understand this lackluster discriminatory ability, it is interesting to look at the overlap between the 2 multivariable models. In the first model examining factors that were likely considered by the cardiologist to make predictions, diuretic or beta-blocker usage and systolic dysfunction were important factors. Both of these factors seem to make intuitive and logical sense. Diuretics and beta blockers are typically used to manage patients with heart failure symptoms and/or arrhythmias,[10] both of which were tied to predefined MAE in our study. Patients with significant past heart failure or arrhythmias may trigger the cardiologist to consider that individual at greater risk. Systolic dysfunction, assessed by echocardiogram, has traditionally been considered a risk factor for adverse events.[11] However, there is limited data that this is true in older Fontan patients. In fact, in 1 study, adult Fontan patients who underwent heart transplant that had preserved systolic function

pretransplant did worse than those with reduced function.[12] Another study similarly found that among 34 patients who had undergone Fontan surgery and required heart transplantation, those with preserved ventricular function had worse survival as compared to those with impaired ventricular function.[13] One interpretation of these data is that cardiologists may overemphasize systolic dysfunction as an important risk factor. In our study, systolic dysfunction was not associated with MAE. This lack of association may in part relate to the complex definition of normal systolic function in a patient with Fontan. The heterogeneity of cardiac lesions, differences between a morphologic right vs left systemic ventricle, and lack of well-defined cutoffs may affect interpretation.

In the multivariable model of patients who actually had a MAE, the most important factor was prior unplanned cardiac admission with OR of 11.6. Given that a repeated admission was the most commonly observed MAE in our study, this makes intuitive sense. Even a single inpatient admission may warrant heightened scrutiny and follow-up.

Significant AV valve insufficiency, more than systolic dysfunction, was associated with risk of MAE with an OR of 8.9. This tracks with accumulating data in which AV valve regurgitation has increasingly been shown to be a strong risk factor for adverse events in this population. Liu and colleagues reported that AV valve operation after the Fontan surgery was associated with higher mortality and need for transplant.[14] In another study of 61 patients post-Fontan with a mean age of 14 years who required AV valve surgery for regurgitation, the 10-year survival was only 57%; 72% of patients experienced arrhythmias, and 20% developed protein-losing enteropathy.[15] In a recent examination of over 1,700 Fontan patients from the Australia and New Zealand cohort, patients with right ventricular dominance who developed moderate or greater AV valve regurgitation had an increased risk of death or transplantation.[16] Interestingly, this was not seen in those with left ventricular dominance.

To improve risk stratification, cardiologists should consider the factors associated with those who experienced MAE. Namely, in addition to the overlap between diuretic or beta-blocker, which was a factor associated with both predicted and actual MAE, attention to AV valve regurgitation and prior unplanned admission are important considerations for those at higher risk. This higher-risk group might benefit from an enhanced strategy for monitoring.

Counseling the patient and family regarding risks remains challenging, in particular for the cardiologist, who has had a longitudinal relationship with their patient over many years. How and when to discuss risk and initiate difficult conversations about morbidity and mortality is critical. Having a better predictive ability to discriminate between the "good Fontan" vs those at higher risk may help to guide the decisions surrounding these conversations.

TABLE 4 Multivariable Models

	OR	95% CI Low	95% CI High	*P* Value
Variables associated with cardiologist prediction of at-risk for MAE vs good Fontan				
Diuretic OR beta-blocker use	5.7	2.5	12.9	<0.001
Systolic dysfunction	3.3	1.5	7.6	0.005
Variables associated with observed MAE				
Prior unplanned cardiac admission	11.6	2.1	65.8	0.006
Diuretic OR beta-blocker use	4.6	1.2	17.6	0.028
≥Moderate AVV regurgitation	8.9	1.0	79.6	0.049

AVV = atrioventricular valve; MAE = major adverse event.

The role of exercise in the long-term success of patients who have had a Fontan operation is becoming increasingly recognized.[17,18] In our study, we asked the patient to self-rate their frequency of vigorous exercise. This was not associated with cardiology predictions or MAE. It is possible that the cardiologist may have considered some subjective assessment of fitness in their categorization of the individual. Unfortunately, we did not have consistent cardiopulmonary exercise testing for our patient population, which might have yielded other findings.

STUDY LIMITATIONS. A limitation of our study was the follow-up period of 12 months. This is a relatively short period of time in which to observe risk, and extension of this to longer-term follow-up may change the predictive nature of the cardiologist's assessment. It is unclear if an extended period of 3 to 5 years, for example, would be associated with improved prediction ability. In addition, the limited sample size of the group that experienced MAE may have restricted the ability to draw conclusions with regard to association. While we did collect baseline laboratory data, we did not have data regarding biomarkers such as troponin or B-type natriuretic peptide, which may be useful in terms of risk stratification. In addition, we did not have consistent access to cardiopulmonary stress test data, 3-dimensional imaging data, or invasive hemodynamics, which might contribute to predictors of risk.

CONCLUSIONS

In summary, cardiologists are only marginally successful at distinguishing between the "good Fontan"

vs the individual at risk for MAE in the outpatient Fontan population over a relatively short time span. Cardiologists focused on those who were taking beta blockers/diuretics and had systolic dysfunction as the highest-risk group. Factors associated with actual MAE included prior unplanned cardiac admission, diuretic/beta-blocker use, and significant AV valve regurgitation. These data highlight the critical need for improved risk stratification models in the Fontan population.

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PERSPECTIVES

COMPETENCY IN PATIENT CARE AND PROCEDURAL SKILLS: In patients with a Fontan, the cardiologist is only able to marginally predict which patients are at highest risk. Factors associated with MAE include diuretic/beta-blocker, significant AV valve regurgitation, and prior unplanned cardiac admission.

TRANSLATIONAL OUTLOOK: Better prediction models are needed to enable accurate counseling, testing, and follow-up for adolescents and adults who have had a Fontan surgery.

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