TABLE 3. Observed and Risk-adjusted Mortality Rates for Hospital Volumes and Complexity Groups

Annual Hospital Volume	I			II			III			IV			Total		
	% in Group	OMR	RAMR	% in Group	OMR	RAMR	% in Group	OMR	RAMR	% in Group	OMR	RAMR	% in Group	OMR	RAMR
<100	42.2	1.85	9.16	33.0	5.76	9.24	34.3	13.35	8.78*	36.2	22.22	7.34	38.2	7.52	8.26*
≥100	57.8	1.05	5.05	67.0	3.85	5.63	65.7	9.72	5.79	63.8	18.91	6.41	61.8	6.28	5.95†
Total	100	1.39		100	4.48		100	10.97		100	20.11		100	6.75	

Observed and Risk-adjusted Mortality Rates for Surgeon Volumes and Complexity Groups

Annual Surgeon Volume	I			II			III			IV			Total		
	% in Group	OMR	RAMR	% in Group	OMR	RAMR	% in Group	OMR	RAMR	% in Group	OMR	RAMR	% in Group	OMR	RAMR
<75	33.7	2.07	10.23	26.3	4.68	7.47	25.5	15.69	9.82*	34.2	23.53	7.80	30.7	8.46	8.77*
≥75	66.3	1.05	5.04	73.7	4.41	6.51	74.5	9.36	5.73	65.8	18.33	6.20	69.3	5.99	5.90†
Total	100	1.39		100	4.48		100	10.97		100	20.11		100	6.75	

Abbreviations: OMR, observed mortality rate; RAMR, risk-adjusted mortality rate.
* Risk-adjusted rate is significantly higher than statewide rate ($P < .05$).
† Risk-adjusted rate is significantly lower than statewide rate ($P < .05$).

TABLE 4. Number of Cases and Risk-adjusted Mortality Rates for Pediatric Cardiac Surgery in New York State from 1992–1995 by Annual Hospital and Surgeon Volume

Surgeon Volumes	Hospital Volumes		Total	Number of Surgeons
	<100	≥100		
<75	8.94‡* 1472†	8.47 726	8.77‡ 2198	21–26
≥75	7.45 1267	5.45§ 3704	5.90§ 4971	9–12
Total	8.26‡ 2739	5.95§ 4430	6.75 7169	
Number of hospitals	7–10	6–9		

* Risk-adjusted mortality rate.
† Number of patients.
‡ Risk-adjusted rate is significantly higher than statewide rate ($P < .05$).
§ Risk-adjusted rate is significantly lower than statewide rate ($P < .05$).

tients undergoing surgery in hospitals with annual volumes of at least 100 performed by surgeons with annual volumes of at least 75 to 8.94% for patients undergoing surgery in hospitals with annual volumes of <100 performed by surgeons with annual volumes of <75. These two rates were significantly lower and significantly higher, respectively, than the statewide rate ($P < .05$), and significantly different from one another ($P < .05$). Risk-adjusted mortality rates for combinations of low-volume surgeons and high-volume hospitals, and of high-volume surgeons and low-volume hospitals, were 8.47% and 7.45%, respectively.

DISCUSSION

The purpose of this study was to examine the relationship between the in-hospital mortality rate for pediatric cardiac procedures and the annual hospital and surgeon volumes for these procedures. However, there are many different pediatric cardiac procedures, each with its own complexity and mortality rate. Consequently, the strategy used to analyze the data was the one used by Jenkins et al,[1] which was to combine procedures into categories on the basis of their complexities/hospital mortality rates, and then to use these groups in addition to patient demographics and risk factors to risk-adjust mortality rates for different ranges of provider volumes. Two advantages of this study relative to the study by Jenkins et al[1] are: 1) a clinical database was available to us for performing the risk-adjustments rather than having to rely on administrative data, and 2) annual surgeon volumes were available for testing the surgeon volume-mortality relationship in addition to the hospital volume-mortality relationship.

In observing the procedure categories, it is important to note that patient selection and the presence of important comorbidities undoubtedly account for differences in mortality between closely related procedures. As an example, patients with severe pulmonary stenosis associated with a dysplastic pulmonary valve are likely to undergo an open pulmonary valvotomy, whereas patients with pulmonary atresia, intact ventricular septum, and hypoplastic right ventricle may be more heavily represented in the group having a closed pulmonary valvotomy. Clearly, the hazard of death is greater in the latter group; consequently, the difference in mortality between open and closed pulmonary valvotomy is likely to be a function of the risk factors associated with the disease state rather than the technical features of the surgery.

Findings of the study were that annual hospital volume and annual surgeon volume were both significantly related to inpatient mortality rates, even after controlling for patient age and several clinical risk factors in addition to procedure complexity. The maximal differentiation in mortality rates between high- and low-volume providers was at 100 procedures annually for hospitals and 75 procedures annually for surgeons. However, in general, higher hospital volumes and higher surgeon volumes were associated with lower risk-adjusted mortality rates across all procedure volumes, so any decision to recommend minimum hospital or surgeon volumes for pediatric cardiac procedures should take into account this fact and practical considerations regarding the geographical distribution of pediatric centers.

It is also important to note that annual hospital