# Unplanned hospital readmissions following congenital heart diseases surgery

## *Prevalence and predictors*

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## ABSTRACT

**الأهداف**: تهدف هذه الدراسة إلى تقدير نسبة إعادة التنويم الغير مبرمج في المستشفى بعد الإصلاح الجراحي لتشوهات القلب الخلقية، كما تم التحقيق عن أسباب إعادة التنويم وعوامل الخطر المتعلقة بذلك.

**الطريقة**: تم من خلال هذه الدراسة الاستعادية مراجعة حالات الإصلاح الجراحي لتشوهات القلب الخلقية في المستشفى الجامعي لجامعة الملك عبد العزيز بجدة. تمثلت حصيلة الدراسة في إعادة التنويم في المستشفى خلال 12 شهرا بعد أول عملية جراحية، مع استبعاد حالات التنويم المبرمج. تم تجميع البيانات المتعلقة بديموغرافية المريض، البيانات الخاصة بإعادة التنويم، إلى جانب البيانات المتعلقة بالفترة المحيطة بالجراحة وتحليلها كعوامل تنبئية لإعادة التنويم.

**النتائج**: بعد إقصاء حالات الوفيات بعد العملية وقبل إعادة تنويم، تم إدراج 189 مريضا في الدراسة حيث بلغت نسبة إعادة التنويم الغير مبرمج 15.9% خلال السنة التالية لعملية الإصلاح الجراحي لتشوه القلب الخلقي. كما أظهرت النتائج علاقة معتدة بين احتمالية إعادة التنويم وكلا من التهوية الآلية قبل الجراحة (قيمة احتمالية ($p<0.001$))، حدوث مضاعفات أثناء العملية الجراحية ($p=0.025$)، تنويم مطول بعد العملية ($p<0.001$)، مضاعفات المبكره ما بعد الجراحة ($p=0.007$)، ومدة مكوث أنبوب النزح ($p=0.011$). أبرز العوامل التنبئية المعتدة لإعادة التنويم الغير مبرمج كانت حداثة السن (12–1 شهرا) وصغر الوزن (أقل من 5 كغ) عند العملية، التهوية الآلية قبل الجراحة، حدوث مضاعفات أثناء العملية الجراحية، تنويم لـ 10 أيام أو أكثر بعد العملية، مدة التنويم بوحدة الرعاية المركزة للأطفال، مدة مكوث أنبوب النزح، حدوث عدوى أو مضاعفات تنفسية أومشاكل تغذية، بنسب أرجحية متفاوتة. اقتصرت عوامل الخطر المستقلة على التهوية الآلية قبل الجراحة والتنويم لـ10 أيام أو أكثر بعد العملية.

**الخاتمة**: كانت نسبة إعادة التنويم متوافقة مع النسب المذكورة في باقي الدراسات. يحسن القيام بدراسات مستقبلية لتقييم الإجراءات المناسبة للتخفيف من عوامل الخطر القابلة للتغيير مثل المضاعفات بعد العملية.

**Objectives:** To estimate the rate of unplanned hospital readmission following surgical repair of congenital heart defects (CHD) and investigate the related causes and risk factors.

**Methods:** A retrospective chart review of all the patients who underwent surgical repair of CHD at King Abdulaziz University Hospital, Jeddah, Saudi Arabia. The study outcome consisted of any hospital admission during the 12 months following the first reparative surgery. Exclusion criteria included planned admissions. Patients' demographic and readmission data as well as the perioperative data were collected and analyzed as factors and predictors of unplanned readmission

**Results:** After the exclusion of the deceased patients, a total of 189 patients were included. The readmission rate was 15.9% during a one-year period following surgery. There was a significant association between the probability of readmission and preoperative mechanical ventilation (MV) ($p<0.001$), intraoperative complications ($p=0.025$), prolonged postoperative length of stay (LOS) ($p<0.001$), early postoperative complication ($p=0.007$), long postoperative MV stay, and drain tube stay ($p=0.011$). Significant predictors of unplanned readmission included young age (1-12 months) and low weight at surgery (<5kg), preoperative MV, intraoperative complications, postoperative LOS ≥10 days, pediatric intensive care unit stay, MV stay, drain tube stay, infections, respiratory complication, and feeding problems. Only the preoperative MV and LOS >10 days were the independent risk factors.

**Conclusion:** Readmission rates were similar to those reported in other studies. Future studies are warranted to investigate suitable actions to alleviate the modifiable risk factors, such as postoperative complications.


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Congenital heart disease (CHD) is the most common congenital disease among newborns in the world.[1] Incidence estimates of CHD before the introduction of echocardiography ranged between 5 and 8 per 1,000 live births, while the current figures refer to approximately 8-12 per 1,000 live births.[2,3] In Saudi Arabia, CHD per 1,000 newborn infants was 2.1 where the data were extracted from stratified listing according to the population census,[4] 5.4 in Al-Qassim,[5] and 7.4 in a study based on the national registry.[6] The burden of CHD is predominant at the southwestern provinces and the northeast region of the Eastern province.[6] The repair of heart congenital defects entails consuming high healthcare costs. Further, patients may experience hemodynamic residua or other types of complications later in their life, a matter which is more prominent in those with complicated anomalies.[7] Therefore, it is plausible that patients with CHD are prone to readmission to the hospital after their initial procedures.

Hospital readmission may constitute a good reflect of the quality of the provided medical care and is associated with increased healthcare costs.[8] Studies have shown that the readmission rate in children was 7% within 30 days of discharge.[9] In particular, following open-heart surgeries in the newborns, unplanned readmissions may have a significant influence on the emotional and financial aspects of the families.[10] Accurate assessment of the readmission-related factors is of a significant implication in order to take the relevant actions to reduce the rates of unnecessary hospitalization and minimize health costs. However, only a small number of studies were performed to assess the prevalence rate of readmission after CHD surgeries in children. This study aimed at analyzing the incidence, causes, and risk factors associated with following CHD surgeries in children.

**Methods.** The current study is a retrospective chart review and includes patients who were subjected to primary surgical repair at the Pediatric Cardiology Unit, King Abdulaziz University Hospital (KAUH), Jeddah, Saudi Arabia between January 2013 and December 2016. It included all cases of children and adolescent (aged ≤14 years) who underwent corrective or palliative surgery based on the type of CHD; and was approved by the Institutional Review Board of KAUH. The study conformed to Helsinki Declaration.

The exclusion criteria included patients who were subjected to surgery after 14 years of age as well as secondary surgery cases.

A semi-structured form was used to collect data. The form included 5 divisions: i) baseline demographic and clinical factors (gender, age at surgery, CHD type, weight at surgery, presence of genetic syndrome, developmental delay, and so on); ii) preoperative factors as the need for mechanical ventilation (MV), preoperative length of stay (LOS)(days), baseline hemoglobin level (normal, low or high), and risk stratification using the risk adjusted classification for congenital heart surgery (RACHS) scale; iii) any intraoperative complications as injuries, bleeding, heart block, cardiac arrest; iv) postoperative data including pediatric intensive care unit (PICU) stay (days), drain tube stay (days), MV stay (days), and LOS from surgery to discharge and postoperative complications (cardiac, respiratory and renal complications, infections, feeding problems, and so on); v) readmission data including time from discharge to first readmission, cause, site (PICU or ward), readmission LOS, and number of readmission during the 12 months after surgery.

According to RACHS classification, cases were divided into 6 categories as previously described by Jenkins et al.[11] Congenital heart disease cases were divided into 2 main groups of defects: group 1 including atrial septal defect, double outlet right ventricle, ventricular septal defect, tricuspid atresia patent ductus arteriosus; and group 2 including tetralogy of fallot, atrioventricular septal defect, transposition of the great arteries, pulmonary atresia, Total anomalous pulmonary venous return, coartaction of the aorta. The classification is based on postoperative length of stay findings that were described in a previous study involving the same population of patients.[12]

*Statistical analysis.* Data were analyzed using Statistical Package for Social Sciences version 21.0 for Windows (IBM SPSS Inc., Chicago, IL, USA). The primary study outcome was hospital readmission during the first year following surgical repair of CHD, and the related variable was analyzed as a binomial variable. Subsequently, participants were divided into 2 groups: readmitted and non-readmitted ones; groups were compared for different factors using Chi-square test or Fisher's exact test for categorical variables and independent t-test for continuous variables. Binary logistic regression was carried out to analyze predictors of readmission; univariate models were used to identify significant predictors and multivariate regression

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models were carried to analyze the significance of these predictors as independent risk factors. A *p* value of <0.05 was considered to reject the null hypothesis.

**Results.** Out of 203 children and young adults who underwent surgical repair of CHD during the study period, 14 were excluded as they died before any readmission. The demographic and clinical characteristics of the 203 patients as well as their surgical outcomes were presented in a previously published paper that analyzed LOS.[13] Consequently, 189 patients were included, 30 (15.9%) were readmitted during the 12 months following congenital heart surgeries. Majority of readmission cases were in ward (27/30, 90.0%), occurred during the first month following discharge (20/30, 66.7%) and were motivated by infection (20/30, 66.7%). Length of stay of readmitted patients was <10 days in 17/30 (56.7%) of the cases (**Table 1**).

***Demographic and baseline clinical factors associated with unplanned hospital readmission***. The percentage of readmissions was higher among younger age categories: <30 days (17.6%) and 1-12 months (26.3%) versus 1-5 years (10.0%) and >5 years (2.8%) ($p$=0.006); low weight at surgery <5 kg (29.4%), 5-10 kg (18.3%) and >10 kg (3.0%) ($p$<0.001); and patients with failure to thrive (35.5%) versus those without (12.0%) ($p$ =0.001) (**Table 2**).

***Perioperative factors of unplanned hospital readmissions.*** Readmission was associated with preoperative MV (40.7% versus 11.7%; $p$<0.001), intraoperative complications (41.7% versus 14.1%; $p$=0.025), extended postoperative LOS (25.7% versus 4.5%; $p$<0.001), and the occurrence of early postoperative complication (21.1% versus 4.9%; $p$=0.005) by comparison to their counterparts. Intraoperative complications were reported in 12

**Table 1 -** Readmissions during the 12 months following surgical repair of congenital heart defects (N=30, 15.9% of total participants).

| Parameter | Category | n (%) |
|---|---|---|
| Site | PICU | 3 (10.0) |
| | Ward | 27 (90.0) |
| Time from discharge to 1st readmission | <30 days | 20 (66.7) |
| | 31 - 45 days | 3 (10.0) |
| | 46 days - 6 months | 4 (13.3) |
| | >6 months - 1 year | 3 (10.0) |
| Readmission LOS (days) | <10 | 17 (56.7) |
| | >=10 | 13 (43.3) |
| Cause of readmission | Infection | 20 (66.7) |
| | Pleural effusion | 3 (10.0) |
| | Pericardial effusion | 1 (3.3) |
| | Other | 6 (20.0) |
| Number of readmissions during the 12 months following surgery* | 1 | 21 (70.0) |
| | 2-3 | 5 (16.7) |
| | ≥4 | 4 (13.3) |

*For the same patient, PICU - pediatric intensive care unit, LOS - length of stay

**Table 2 -** Participants demographic and clinical characteristics and their correlation with postoperative length of hospital stay (N=189, excluding 14 deaths).

| Parameter | Category | No (n=173) | Yes (n=30) | *P*-value |
|---|---|---|---|---|
| *Demographic data* | | | | |
| Age at surgery (category) | <30 days | 14 (82.4) | 3 (17.6) | 0.006* |
| | 1-12 months | 56 (73.7) | 20 (26.3) | |
| | 1-5 years | 54 (90.0) | 6 (10.0) | |
| | >5 years | 35 (97.2) | 1 (2.8) | |
| Gender | Male | 79 (80.6) | 19 (19.4) | 0.170 |
| | Female | 80 (87.9) | 11 (12.1) | |
| Nationality | Non-Saudi | 144 (83.2) | 29 (16.8) | 0.475‡ |
| | Saudi | 15 (93.8) | 1 (6.3) | |
| *Clinical data* | | | | |
| Prematurity | Yes | 2 (84.4) | 29 (15.6) | 0.406‡ |
| | No | 157 (66.7) | 1 (33.3) | |
| Defect group | Group 1 | 74 (84.1) | 14 (15.6) | 0.990 |
| | Group 2 | 85 (84.2) | 16 (15.8) | |
| Main defect | VSD | 38 (88.4) | 5 (11.6) | 0.569 |
| | TOF | 35 (89.7) | 4 (10.3) | |
| | TGA | 25 (80.6) | 6 (19.4) | |
| | AVSD | 12 (75.0) | 4 (25.0) | |
| | ASD | 9 (100) | 0 | |
| | DORV | 5 (71.4) | 2 (28.6) | |
| | Pulm. atresia | 5 (100) | 0 | |
| | Tricus. atresia | 4 (66.7) | 2 (33.3) | |
| | TAPVC | 4 (80.0) | 1 (20.0) | |
| | CoA | 4 (80.0) | 1 (20.0) | |
| | PDA | 3 (100) | 0 | |
| | Other† | 15 (75.0) | 5 (25.0) | |
| Number of defects | One defect | 132 (83.5) | 26 (16.5) | 0.791‡ |
| | ≥2 defects | 27 (87.1) | 4 (12.9) | |
| Genetic syndrome | None | 134 (84.3) | 25 (15.7) | 1.000‡ |
| | Yes | 25 (83.3) | 5 (16.7) | |
| Past heart surgery | No | 142 (84.5) | 26 (15.5) | 0.751‡ |
| | Yes | 17 (81.0) | 4 (19.0) | |
| Weight at surgery (kg) | <5 | 36 (70.6) | 15 (29.4) | <0.001* |
| | 5-10 | 58 (81.7) | 13 (18.3) | |
| | >10 | 65 (97.0) | 2 (3.0) | |
| Failure to thrive | No | 139 (88.0) | 19 (12.0) | 0.001* |
| | Yes | 20 (64.5) | 11 (35.5) | |
| Developmental delay | No | 141 (85.5) | 24 (14.5) | 0.190 |

Values are presented as frequencies and percentages (%), unless otherwise specified. *statistically significant result ($p$<0.05), †other defects are presented in a previous paper[12], ‡ significance level calculated using Fisher's exact test VSD - ventricular septal defect, TOF - tetralogy of fallot, TGA - transposition of the great arteries, AVSD - atrioventricular septal defect, ASD - atrial septal defect, DORV - double-outlet right ventricle, TAPVC - total anomalous pulmonary venous return, CoA - coartaction of the aorta, PDA - patent ductus arteriosus, Pulm. atresia - pulmonary atresia, Tricus. atresia - tricuspid atresia

patients (6.3%) and included 3 cases of cardiac arrest, 3 cases of injuries, 3 cases of bleeding, 2 cases of heart block, and one case of diaphragmatic paralysis. Further, long postoperative MV stay ($p$=0.007) and drain tube stay ($p$=0.011) were associated with higher percentage of readmissions (**Table 3**).

***Predictors of unplanned readmission.*** In univariate regression models, age at surgery 1-12 months (odds ratio [OR]=12.50; $p$=0.016), low weight at surgery (<5 kg: OR=13.54, $p$=0.001; 5-10 kg: OR=7.28, $p$=0.011), preoperative MV (OR=5.17, $p$<0.001), as well as intraoperative complications (OR=4.34, $p$=0.019) were significant predictors of unplanned readmission. Postoperative predictors included postoperative LOS≥10 days (OR=7.28, $p$<0.001), PICU stay (OR=1.07, $p$=0.001), MV stay (OR=1.14, $p$=0.002), drain tube stay (OR=1.05, $p$=0.016), infections (OR=3.29, $p$=0.006), respiratory complication (OR=4.32, $p$<0.001), and presence of feeding problems (OR=3.04, $p$=0.022) (**Table 4**). Based on significant predictors in univariate regression analysis, various multivariate models were tested; among these a 4-factor model showed preoperative MV (OR=3.95, $p$=0.005) and postoperative LOS >10 days (OR=3.60, $p$=0.038) to be the only independent risk factors of readmission (**Table 5**).

## Discussion.

The present study probed into unplanned hospital readmission following CHD first repair surgery and showed that one in 7 patients are readmitted in hospital during the 12 months of postoperative follow up; by exclusion of those who deceased during intervention or in early postoperative time. Further, this study highlighted 2 independent risk factors for unplanned readmission including preoperative MV and extended postoperative LOS (>10 days).

Unexpectedly, plausible parameters such as RACHS category, intraoperative complications, and the occurrence and number of postoperative complications were not demonstrated to be independently associated with unplanned hospital readmission; although, these showed to be statistically significant predictors in univariate regression models.

Despite the insufficient consensus about its exact quantifiable performance parameters, hospital readmission remains to be an essential element of the decision-making process for healthcare providers and policymakers who strive for delivering optimal quality care along with consumption of minimal resources.[14,15] Readmission is basically linked to index hospitalization in general. During the past 2 decades, postoperative

**Table 3 -** Perioperative factors of unplanned hospital readmissions following surgical repair of congenital heart defects.

| Parameter | Category | No (N=173) | Yes (N=30) | *P*-value |
|---|---|---|---|---|
| ***Preoperative data*** | | | | |
| Preoperative MV | Yes | 143 (88.3) | 19 (11.7) | <0.001* |
| | No | 16 (59.3) | 11 (40.7) | |
| Preoperative hemoglobin level | Normal | 43 (82.7) | 9 (17.3) | 0.715 |
| | Low | 91 (83.5) | 18 (16.5) | |
| | High | 25 (89.3) | 3 (10.7) | |
| Preoperative LOS (days) | <2 | 81 (89.0) | 10 (11.0) | 0.100 |
| | 2-5 | 38 (84.4) | 7 (15.6) | |
| | >5 | 40 (75.5) | 13 (24.5) | |
| RACHS category | 1 | 11 (100) | 0 | 0.011* |
| | 2 | 102 (84.3) | 19 (15.7) | |
| | 3 | 35 (85.4) | 6 (14.6) | |
| | 4 | 8 (80.0) | 2 (20.0) | |
| | 5 | 0 | 0 | |
| | 6 | 0 | 2 (100) | |
| Intraoperative data | | | | |
| Surgical complications | No | 152 (85.9) | 25 (14.1) | 0.025* |
| | Yes | 7 (58.3) | 5 (41.7) | |
| ***Postoperative data*** | | | | |
| Postoperative LOS (days) | <10 | 84 (95.5) | 4 (4.5) | <0.001*† |
| | 10+ | 75 (74.3) | 26 (25.7) | |
| PICU stay (days) | <2 | 11 (100) | 0 | <0.001* |
| | 2-5 | 89 (90.8) | 9 (8.2) | |
| | 6-10 | 40 (83.3) | 8 (16.7) | |
| | >10 | 19 (59.4) | 13 (40.6) | |
| Mechanical ventilation (days) | <1 | 71 (91.0) | 7 (9.0) | 0.007* |
| | 1-5 | 74 (84.1) | 14 (15.9) | |
| | 6-10 | 9 (60.0) | 6 (40.0) | |
| | >10 | 5 (62.5) | 3 (37.5) | |
| Drain tube stay (days) | <3 | 5 (100) | 0 | 0.011* |
| | 3-5 | 80 (93.0) | 6 (7.0) | |
| | 6-10 | 39 (76.5) | 12 (23.5) | |
| | >10 | 32 (72.7) | 12 (27.3) | |
| | No drain | 3 (100) | 0 | |
| ***Outcomes and complications*** | | | | |
| Any complication | None | 58 (95.1) | 3 (4.9) | 0.005*† |
| | 1 or more | 101 (78.9) | 27 (21.1) | |
| Infection | No | 93 (91.2) | 9 (8.8) | 0.004* |
| | Yes | 66 (75.9) | 21(24.1) | |
| Cardiac complications | No | 129 (84.3) | 24 (15.7) | 0.885 |
| | Yes | 30 (83.3) | 6 (16.7) | |
| Feeding complications | No | 142 (86.6) | 22 (3.4) | 0.018* |
| | Yes | 17 (68.0) | 8 (32.0) | |
| Respiratory complication | No | 108 (92.3) | 9 (7.7) | <0.001* |
| | Yes | 51 (70.8) | 21 (29.2) | |
| Transfusion | No | 140 (83.8) | 27 (16.2) | 1.000† |
| | Yes | 19 (86.4) | 3 (13.6) | |
| Number of complications | 0 | 58 (95.1) | 3 (4.9) | <0.000* |
| | 1 | 53 (88.3) | 7 (11.7) | |
| | 2 | 27 (67.5) | 13 (32.5) | |
| | 3 | 14 (87.5) | 2 (12.5) | |
| | 4+ | 7 (58.3) | 5 (41.7) | |
| Revision surgery | No | 158 (84.9) | 28 (15.1) | 0.066† |
| | Yes | 1 (33.3) | 2 (66.7) | |

Values are frequencies and percentage (%), unless otherwise specified, *statistically significant result ($p$<0.05), †significance level calculated using Fisher's exact test, LOS - length of stay, MV - mechanical ventilation

**Table 4 -** Perioperative factors of unplanned hospital readmissions following surgical repair of congenital heart defects.

| Predictor | Category/value | OR | 95%CI | | *P*-value |
|---|---|---|---|---|---|
| ***Demographic predictors*** | | | | | |
| Age at surgery (category) | <30 days | 7.50 | 0.72 | 78.37 | 0.092 |
| | 1-12 months | 12.50 | 1.61 | 97.32 | 0.016* |
| | 1-5 years | 3.89 | 0.45 | 33.70 | 0.218 |
| | >5 years | (ref) | - | - | 0.019* |
| Baseline clinical predictors | | | | | |
| | <5 | 13.54 | 2.93 | 62.57 | 0.001* |
| Weight at surgery (kg) | 5-10 | 7.28 | 1.58 | 33.65 | 0.011* |
| | >10 | (ref) | - | - | 0.003* |
| Preoperative predictors | | | | | |
| Mechanical ventilation | Yes | 5.17 | 2.09 | 12.79 | <0.001* |
| RACHS category | Low (1-3) | (ref) | - | - | - |
| | High (4-6) | 2.96 | 0.83 | 10.57 | 0.095 |
| Intraoperative complications | Yes | 4.34 | 1.28 | 14.76 | 0.019* |
| ***Postoperative predictors*** | | | | | |
| Postop LOS | (Days) | 1.03 | 1.01 | 1.06 | 0.003* |
| Postop LOS | 10+ days | 7.28 | 2.43 | 21.82 | <.001* |
| PICU stay | (Days) | 1.07 | 1.03 | 1.12 | 0.001* |
| MV stay | (Days) | 1.14 | 1.05 | 1.24 | 0.002* |
| Drain tube stay | (Days) | 1.05 | 1.01 | 1.10 | 0.016* |
| Infectious complication | Yes | 3.29 | 1.42 | 7.63 | 0.006* |
| Respiratory complication | Yes | 4.32 | 1.92 | 0.73 | <0.001* |
| Diet/feeding problem | Yes | 3.04 | 1.17 | 7.88 | 0.022* |
| Any complication | Yes | 5.17 | 1.50 | 17.78 | 0.009* |

OR - odds ratio, CI - confidence interval, ref - reference category, LOS - length of stay, MV - mechanical ventilation, RACHS - risk adjusted classification for congenital heart surgery, PICU - pediatric intensive care unit, *statistically significant result ($p$<0.05), correlation coefficient of the model $r^2$=0.628, the regression model in presented in fitted line plot in **Figure 3**.

outcomes have been substantially improved in regards to mortality.[16,17] Focusing on the congenital heart surgeries, several attempts have been established to reduce hospital LOS and the associated cost, such as employing a critical pathway[18] or fast-track extubation,[19] yielding promising outcomes. However, readmissions that may remain high in CHD patients should drive similar attention, as they yield comparable burden in term of morbidity and health expenditure.

In the present study, the rate of readmission was 10.5% within 30 days and 15.9% after one year of discharge following the congenital heart surgeries. The majority of studies from literature focused on the 30-day time frame. For example, a similar figure was reported in a previous study,[20] where 10.8% of children with CHD in Atlanta were readmitted after their corrective surgeries. This was also typically consistent with a 10.5% readmission rate as per results of a multi-institutional analysis in the United States.[21] A slightly lower rate (9.7%) was reported among the children who underwent elective cardiac surgery procedures.[22] On the other hand, in a large population-based study in Canada, the rate of readmission within 30 days was larger (14%) in children aged 0-17 years during a 15-year period.[10] Readmission rates may differ by type of CHD and or procedure; for example, Mackie et al[23] found that the readmission rates were 3.8% following arterial switch procedures, while 11.4% readmissions were reported after Norwood procedures. In general, the readmission rates in KAUH were relatively similar to those of other studies. However, readmission to other hospitals may interfere the true rates, since the patient with an urgent intervening illness (comorbid with CHD) may be readmitted to another hospital closer to his/her home.

Preoperative MV and postoperative LOS can be considered as nonspecific parameters that may be independently associated to other more clinically significant factors such as RACHS category, type of CHD, type of surgery; however, investigating these associations was beyond the scope of this study. Consistent with our findings, Kogon et al[20] found also that MV was one of the associated preoperative factors with the likelihood of readmission, which was in agreement with Saharan et al.[13] Actually, the preoperative criteria of the patients reflect the severity

**Table 5 -** Independent risk factors of readmission following surgical repair of congenital heart defects (multivariate binary logistic regression).

| Model/Predictor | Category | OR | 95%CI | | *P*-value |
|---|---|---|---|---|---|
| ***Model 1*** | | | | | |
| Demographic predictors | | | | | |
| Age at surgery (category) | <30 days | 0.47 | 0.01 | 17.67 | 0.683 |
| | 1-12 months | 2.77 | 0.12 | 66.58 | 0.530 |
| | 1-5 years | 1.64 | 0.09 | 31.44 | 0.741 |
| | >5 years | (ref) | - | - | - |
| Baseline clinical predictors | | | | | |
| | <5 | 3.62 | 0.24 | 53.65 | 0.349 |
| Weight at surgery (kg) | 5-10 | 4.22 | 0.42 | 42.33 | 0.221 |
| | >10 | (ref) | - | - | - |
| ***Preoperative predictors*** | | | | | |
| Mechanical ventilation | Yes | 2.95 | 0.80 | 10.82 | 0.103 |
| Intraoperative complications | Yes | 2.28 | 0.49 | 10.61 | 0.293 |
| Postoperative predictors | | | | | |
| Postop LOS | (days) | 0.99 | 0.95 | 1.02 | 0.466 |
| Postop LOS | 10+ days | 3.30 | 0.89 | 12.25 | 0.074 |
| PICU stay | (Days) | 1.02 | 0.93 | 1.11 | 0.705 |
| MV stay | (Days) | 1.02 | 0.86 | 1.21 | 0.810 |
| Drain tube stay | (Days) | 1.03 | 0.96 | 1.10 | 0.395 |
| Infectious complication | Yes | 1.27 | 0.38 | 4.18 | 0.697 |
| Respiratory complication | Yes | 2.06 | 0.65 | 6.55 | 0.219 |
| Diet/feeding problem | Yes | 1.80 | 0.49 | 6.63 | 0.378 |
| Any complication | Yes | 1.05 | 0.17 | 6.41 | 0.959 |
| Model 2 | | | | | |
| Baseline clinical predictors | | | | | |
| | <5 | 4.44 | 0.76 | 26.12 | 0.099 |
| Weight at surgery (kg) | 5-10 | 6.59 | 1.32 | 32.98 | 0.022* |
| | >10 | (ref) | - | - | - |
| ***Preoperative predictors*** | | | | | |
| Mechanical ventilation | Yes | 2.94 | 0.87 | 9.94 | 0.083 |
| Intraoperative complications | Yes | 1.57 | 0.36 | 6.83 | 0.550 |
| Postoperative predictors | | | | | |
| Postop lenght of stay | 10+ days | 3.29 | 0.89 | 12.17 | 0.074 |
| PICU stay | (Days) | 0.99 | 0.91 | 1.07 | 0.777 |
| MV stay | (Days) | 1.05 | 0.90 | 1.23 | 0.517 |
| Drain tube stay | (Days) | 1.01 | 0.96 | 1.07 | 0.701 |
| Infectious complication | Yes | 1.19 | 0.38 | 3.80 | 0.764 |
| Respiratory complication | Yes | 1.87 | 0.62 | 5.62 | 0.265 |
| Diet/feeding problem | Yes | 1.48 | 0.44 | 4.95 | 0.522 |
| Any complication | Yes | 1.11 | 0.20 | 6.32 | 0.904 |
| Model 3 | | | | | |
| Baseline clinical predictors | | | | | |
| | <5 | 4.32 | .78 | 24.08 | 0.095 |
| Weight at surgery (kg) | 5-10 | 6.23 | 1.28 | 30.31 | 0.023* |
| | >10 | (ref) | - | - | - |
| ***Preoperative predictors*** | | | | | |
| Mechanical ventilation | Yes | 3.11 | 1.00 | 9.65 | 0.049* |
| Postoperative predictors | | | | | |
| Postop length of stay | 10+ days | 3.90 | 1.14 | 13.34 | 0.030* |
| MV stay | (Days) | 1.05 | .97 | 1.14 | 0.241 |
| Respiratory complication | Yes | 2.04 | .76 | 5.46 | 0.156 |
| ***Model 4*** | | | | | |
| Preoperative predictors | | | | | |
| Mechanical ventilation | Yes | 3.95 | 1.50 | 10.40 | 0.005* |
| Postoperative predictors | | | | | |
| Postop length of stay | 10+ days | 3.60 | 1.07 | 12.07 | 0.038* |
| MV stay | (Days) | 2.02 | 0.77 | 5.26 | 0.152 |
| Respiratory complication | Yes | 1.07 | 0.98 | 1.16 | 0.112 |

OR - odds-ratio, CI - confidence interval, MV - mechanical ventilation

of their condition, where the need for longer MV associated with higher RACHS category indicated an increased burden of CHD. This in turn would require readmission following surgeries as the patient might experience significant hemodynamic instability and risk of hospital-acquired infection.[24] Indeed, reports have shown that the patients with a complex CHD had a 2.3-4.1 greater risk of readmission after the index hospitalization.[25]

Total postoperative LOS for more than 10 days and PICU LOS were included as independent risk factors of readmission in the present study. This finding is consistently reported in most of the studies.[10,13,20,23] In addition, Smith et al[21] have shown that the overall hospital LOS and PICU LOS were approximately 2-fold longer in the readmitted CHD patients. This was in agreement with the findings of Kogon et al,[20] where the total postoperative LOS for more than or the same period was an independent predictor of readmission (relative risk [RR] 4.24, 95% CI 2.26 to 7.96, $p<0.0001$) along with preoperative failure to thrive and the Hispanic ethnicity. Actually, the prolonged LOS is potentially explained by greater complicated conditions along with the lack of support in the outpatient setting.[25] Further, the high rates of postoperative infection may represent a major contributor in extending the LOS as demonstrated in our previous study.[12] In addition to increasing the liability to readmission, prolonged LOS in the hospital would consume a great amount of inpatient resources that could be originally prevented if adequately handled.

Although not being an independent risk factor, the occurrence of any postoperative complication was associated with 5.17 odd probability of readmission during the 12 months following surgery; with great significance for respiratory complications, infections and diet/feeding problems. However, this study did not explore the relationship between postoperative complications and the causes of readmission; reports from literature highlight the high prevalence of respiratory problems and infections in readmission among CHD patients. In the studies of Kogon et al[20] and Saharan et al,[13] pleural effusion was the leading cause of readmission following CHD surgeries, while the respiratory causes in general were the main etiologies of readmission in a study by Smith et al.[21] Drainage tube stay was another factor that was statistically associated to readmission after CHD repair without being an independent risk factor. Pleural effusion continues to be real problem for the patients during the postoperative period and, if it persists for long time, it will cause a significant morbidity with prolongation of LOS. In

our experience, a significant number of complications of Fontan surgery that caused readmission were related protein loosing enteropathy PLE and lymphatic dysfunctions. The exact reason for postoperative pleural effusion has not been clearly identified although some evidences have shown that the increase in pulmonary artery pressure, reduction of the ventricular function, and prolonged MV contribute to longer drainage tube stay.[26,27] It is worthy to note that Glenn and Fontan procedures are the most common procedures wherein pleural effusion is observed[13] despite the successful approach to reduce the overall drainage tube stay by a recent study by Pike et al.[28]

Similarly, infection represented one of the most prevalent cause of readmission in CHD patients. A recent study including 16 developing countries revealed that postoperative infection contributed significantly to morbidity and mortality after CHD surgery, leading to longer duration of postoperative MV and longer LOS in the PICU.[29] Additionally, the risk of infection would be substantially increased in younger cases. Infants were more likely to be readmitted independent of the severity of their condition.[30] This may be explained by their low physiologic reserve that might render a great risk of acquiring viral infection. From another perspective, Mackie et al[10] suggested that there may be a less tendency of the physicians to hospitalize infants upon the incidence of complications when compared to older children.

The aforementioned observations should be interpreted within the boundaries of the study limitations; such as the retrospective design that generally entails considerable bias and lack of some key variables, which hinder adequate analysis of independent risk factors and confounders and their effect on the postoperative outcomes. Moreover, small sample size reduced the statistical power of some analysis, notably subgroup analysis by type of procedure, type of CHD, so on and their effect on readmission rate. Another important limiting factor is that some patients could not be included as they may be readmitted to other hospitals after their index hospitalization at KAUH. It is possible also that home nursing care and clinic visits following the surgery may be of a significant role that should be born in mind. Finally, available data did not enable investigating further factors such as the surgical proficiency of the surgeons, which may affect the surgical outcomes and subsequent complications and readmission.

In conclusion, approximately one in 7 CHD patients are re-hospitalized during the 12 months following first repair surgery, and this rate is similar to that reported in other studies. Re-hospitalization was independently predicted by preoperative MV and extended postoperative LOS (>10 days), both being probably linked to other more specific, modifiable factors that should be identified to reduce the rate of readmission and the related morbidity and costs. Other significant factors associated with re-hospitalization that were identified in this study; among these younger age, low weight at surgery, and preoperative MV, in addition to intra- and postoperative complications, drain tube stay, and presence of feeding problems. It is therefore recommended to take the suitable actions in order to control the modifiable risk factors such as infections as well as considering the possible role of surgical expertise in preventing the postoperative complications. This would ultimately serve a promising approach to reduce burden with to health and financial aspects.

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