Original Article

Patient Outcomes and Characteristics in a Contemporary Quaternary Canadian Cardiac Intensive Care Unit
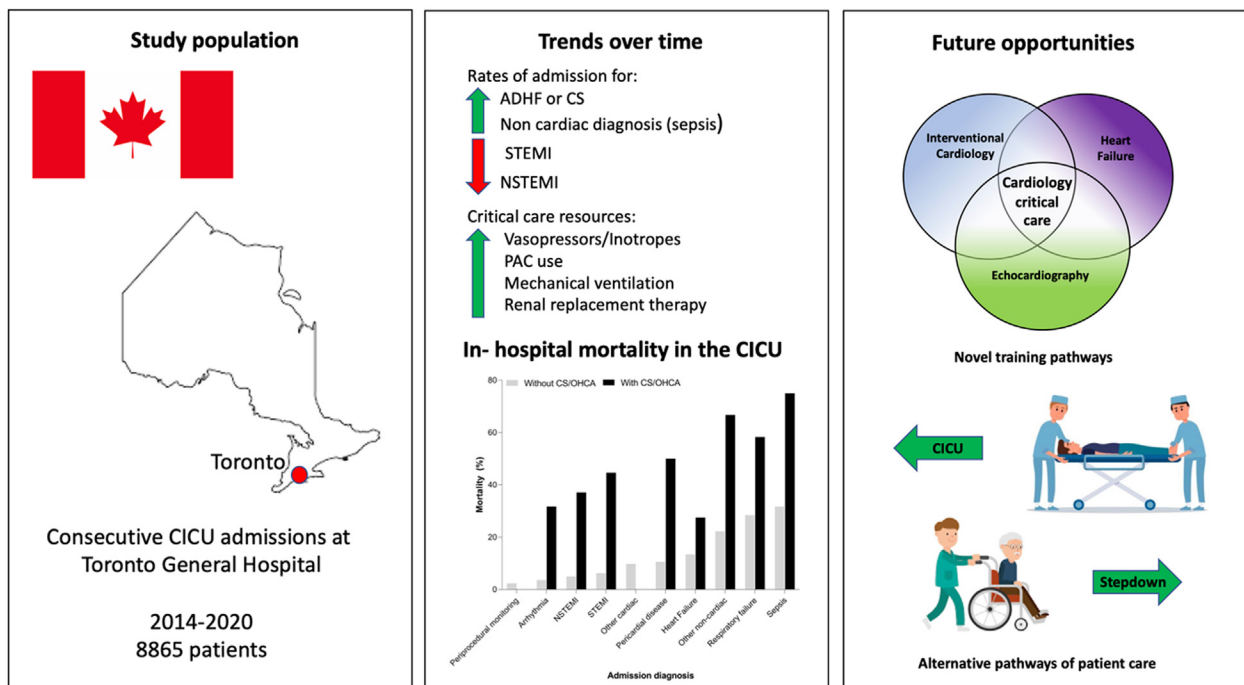
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Study population

Consecutive CICU admissions at Toronto General Hospital

2014-2020
8865 patients

Trends over time

Rates of admission for:
▲ ADHF or CS
Non cardiac diagnosis (sepsis)
▼ STEMI
NSTEMI

Critical care resources:
▲ Vasopressors/Inotropes
PAC use
Mechanical ventilation
Renal replacement therapy

In- hospital mortality in the CICU

Future opportunities

Novel training pathways

Alternative pathways of patient care

ABSTRACT

Background: The modern-day cardiac intensive care unit (CICU) has evolved to care for patients with acute critical cardiac illness. We describe the current population of cardiac patients in a quaternary CICU.

Methods: Consecutive CICU patients admitted to the CICU at the Toronto General Hospital from 2014 to 2020 were studied. Patient

RÉSUMÉ

Introduction : L'unité de soins intensifs de cardiologie (USIC) d'aujourd'hui a évolué vers des soins aux patients atteints d'une maladie cardiaque aiguë en phase critique. Nous décrivons la population actuelle de patients cardiaques d'une USIC quaternaires.

Méthodes : Les patients consécutifs d'USIC admis à l'USIC de l'Hôpital général de Toronto de 2014 à 2020 ont fait l'objet de l'étude. Les

demographics, admission diagnosis, critical care resources, complications, in-hospital mortality, and CICU and hospital length of stay were recorded.

Results: A total of 8865 consecutive admissions occurred, with a median age of 64.9 years. The most common primary cardiac diagnoses were acute decompensated heart failure (17.8%), non ST-elevation myocardial infarction (16.8%), ST-elevation myocardial infarction (15.5%), and arrhythmias (14.7%). Cardiogenic shock was seen in 13.2%, and out-of-hospital cardiac arrest in 4.1%. A noncardiovascular admission diagnosis accounted for 13.9% of the cases. Over the period studied, rates of admission were higher for cardiogenic shock ($P < 0.001$ for trend), with a higher use of critical care resources. Additionally, rates of admission were higher in female patients and those who had chronic kidney disease and diabetes. The in-hospital mortality rate of all CICU admissions was 13.2%, and it was highest in those with noncardiac conditions, compared to the rate in those with cardiac diagnoses (29.4% vs 10.6%, $P < 0.001$).

Conclusions: Given the trends of higher acuity of patients with cardiac critical illness, with higher use of critical care resources, education streams for critical care within cardiology, and alternative pathways of care for patients who have lower-acuity cardiac disease remain imperative to manage this evolving population.

données démographiques des patients, le diagnostic à l'admission, les ressources en soins aux patients en phase critique, les complications, la mortalité intrahospitalière, et la durée de séjour à l'hôpital et à l'USIC ont été enregistrés.

Résultats : Il y a eu un total de 8 865 admissions consécutives dont les patients avaient un âge médian de 64,9 ans. Les diagnostics principaux les plus fréquents de maladies cardiaques étaient l'insuffisance cardiaque aiguë décompensée (17,8 %), l'infarctus du myocarde sans élévation du segment ST (16,8 %), l'infarctus du myocarde avec élévation du segment ST (15,5 %) et les arythmies (14,7 %). Le choc cardiogénique a été observé chez 13,2 %, et l'arrêt cardiaque hors de l'hôpital, chez 4,1 %. Un diagnostic d'admission de maladie non cardiovasculaire représente 13,9 % des cas. Durant la période étudiée, les taux d'admission en raison d'un choc cardiogénique étaient plus élevés ($P < 0,001$ pour la tendance), et entraînaient une utilisation plus élevée de ressources en soins aux patients en phase critique. De plus, les taux d'admission étaient plus élevés chez les patientes, et chez ceux qui avaient une insuffisance rénale chronique et un diabète. Le taux de mortalité intrahospitalière de toutes les admissions à l'USIC était de 13,2 %, et il constituait le taux le plus élevé chez ceux qui avaient des maladies non cardiaques comparativement au taux chez ceux qui avaient des diagnostics de maladies cardiaques (29,4 % vs 10,6 %, $P < 0,001$).

Conclusions : Compte tenu des tendances d'accroissement de la gravité de l'état des patients atteints d'une maladie cardiaque en phase critique et de la plus grande utilisation des ressources en soins aux patients en phase critique, des volets de formation en soins aux patients en phase critique en cardiologie et d'autres protocoles de soins des patients qui ont une maladie cardiaque de plus faible gravité demeurent essentiels à la prise en charge de cette population grandissante.

The coronary care unit as first developed in 1962 was responsible for providing cardiac care to patients presenting with acute myocardial infarction, with a focus on arrhythmia management and acute resuscitation.[1] This development in care led to a 20% reduction in post-myocardial infarction mortality in the following 2 years.[2] Over the past few decades, with advances in diagnostic and interventional cardiac care, the modern-day cardiac intensive care unit (CICU) has evolved to manage patients with a high degree of comorbid illness who have increased needs for advanced invasive support. Multiple single and multicentre registries have identified the evolving complexity of the cardiac patient with higher acuity of illness and intensity of CICU resource allocation.[3-10] Often, noncardiac patients with cardiac comorbid disease are cared for in the CICU if the medical surgical intensive care unit (ICU) is at capacity. In order to maintain the workflow of this dynamic patient population, standardization of care pathways and quality-improvement programs are needed to optimize patient

care in this complex environment.[11,12] The purpose of this retrospective registry is to understand the patient characteristics of those presenting to a high-volume Canadian contemporary quaternary CICU, including admission diagnosis, resource use, and outcomes, as a means to understand current care processes and optimize work flow in the acute care setting.

Methods

Study population

We studied consecutive admissions of adults (≥ 18 years of age) to the CICU at the Toronto General Hospital, Peter Munk Cardiac Centre in Ontario, Canada from January 1, 2014 to December 30, 2020. No exclusion criteria were used for this study. The CICU is a 14-bed unit that can provide the highest levels of care (level-3 ICU) in supporting patients with advanced and prolonged support for multiple-organ failure. The CICU serves as a regional resource for patients who have been resuscitated post-out-of-hospital cardiac arrest (OHCA), those with cardiac disease in the adult congenital heart disease population, and those needing cardiogenic shock (CS) and advanced heart failure (HF) therapies (orthotopic heart transplantation and mechanical circulatory support). The CICU is a closed unit that admits primarily patients with a cardiac diagnosis but may support patients who have acute noncardiac conditions.

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The CICU is supported by a multidisciplinary team comprised of intensive care-trained nursing staff, physicians (attending cardiologists and cardiac intensivists), senior cardiology trainees, junior house staff (from general internal medicine, anesthesia, cardiac and vascular surgery, and emergency medicine), and allied health professionals (pharmacists, respiratory therapists, dietitians, physiotherapists, occupational therapists, and social workers). The institution has access to subspecialties (both medical and surgical) that provide consultation and support for the complex comorbid illnesses seen in this population. Critical care consultation is accessible if needed and is initiated by the CICU attending for acute noncardiac conditions (eg, respiratory failure). Patients who require extracorporeal membrane oxygenation are transferred to a medical-surgical ICU and are not treated in the CICU.

In order to evaluate CICU trends within the study period, the cohort was analyzed yearly from 2014 to 2020. At our institution, 2 intensivist-trained cardiologists attended in the CICU from 2018 onward. In 2020, the critical care resources became hospital-shared resources due to the COVID-19 pandemic.

Data collection and measurement

Demographics, preexisting comorbid illness, care trajectory while admitted to the CICU, and outcomes (CICU and hospital length of stay [LOS], and in-hospital mortality) were recorded as part of ongoing quality-improvement initiatives. Data were obtained from the hospital electronic medical record, and the CICU admission diagnosis was derived from review of the chart rather than the discharge diagnosis found on the discharge summary. A secondary diagnosis of OHCA or CS (defined by the intra-aortic balloon pump-shock II trial)[13] could be selected, but a primary diagnosis would also have to be identified (ie, patient presented with an acute ST-elevation myocardial infarction [STEMI] and an OHCA). The initial diagnoses were clustered as STEMI, non-STEMI/unstable angina (NSTEMI), acute decompensated heart failure (ADHF), arrhythmia, postprocedural monitoring (eg, percutaneous mitral valve repair, or transcatheter aortic or pulmonary valve replacement), pericardial diseases, sepsis, respiratory failure, and other cardiac (eg, myocarditis, infective endocarditis, being a potential heart transplant recipient) and noncardiac conditions (eg, gastrointestinal hemorrhage, drug overdose, diabetic ketoacidosis). Patients with ADHF comprised those with both ischemic and nonischemic cardiomyopathy who presented with HF symptoms without an acute coronary syndrome. Critical care and hospital resources that were recorded include percutaneous coronary intervention (PCI), invasive mechanical ventilation (IMV), IABP, Impella 2.5/CP/5.0 (Abiomed, Danvers, MA) support, pulmonary artery catheterization (PAC), initiation of renal replacement therapy (RRT), and use of inotropes and vasopressors. ICU-related complications, including central line-associated blood stream infections (CLABSI—defined as a primary bloodstream infection that develops in patient with a new central line placed within 48 hours, without another apparent source of infection), sepsis (defined as alteration of mental status, respiratory rate of > 22 breaths per minute, a systolic blood pressure < 100 mm Hg; did not include those

Table 1. Demographic and baseline characteristics of patients admitted to the cardiac intensive care unit (CICU; N = 8865)

Variable	Total cohort (N = 8865)
Age, y	64.9 (53.2–76.1)
Female	3042 (34.3)
BMI, kg/m^2	26.3 (23.0–30.3)
Source of admission	
Emergency department (UHN or SHS)	3299 (37.2)
Transfer from other ICU	1428 (16.1)
Transfer from ward	4121 (46.5)
Primary admission diagnosis	
STEMI	1373 (15.5)
NSTEMI	488 (16.8)
Acute decompensated heart failure	1576 (17.8)
Arrhythmias	1301 (14.7)
Post cardiac procedure monitoring	1030 (11.6)
Pericardial disease	247 (2.8)
Other cardiac conditions	616 (7.0)
Sepsis	315 (3.6)
Respiratory failure	390 (4.4)
Other noncardiac conditions	529 (7.0)
Secondary diagnosis	
Cardiogenic shock	1168 (13.2)
OHCA	366 (4.1)
Pre-admission comorbid illness	
Hypertension	4346 (49.0)
Diabetes mellitus	2480 (28.0)
Dyslipidemia	3265 (36.8)
History of previous MI	1585 (17.9)
History of previous PCI	1358 (15.3)
Chronic kidney disease	1622 (18.3)
Cerebrovascular accident	769 (8.7)
Peripheral vascular disease	442 (5.0)
Congestive heart failure	2599 (29.3)
Atrial fibrillation/flutter	2163 (24.3)
Ventricular arrhythmia	458 (5.2)
Congenital heart disease	499 (5.6)
COPD	658 (7.4)
Mental illness	656 (7.4)
Medication at admission	
ASA	3187 (36.0)
Other antiplatelet agent	1174 (13.3)
ACEI or ARB	3235 (36.5)
ARNI	144 (1.6)
Beta-blockers	4029 (45.5)
Statins	4388 (43.9)
Loop diuretics	2820 (31.9)
Insulin	724 (8.2)
Critical care resource utilization	
Mechanical ventilation	1310 (14.8)
BIPAP use	234 (2.6)
Vasopressor or inotrope use	2355 (26.6)
Pulmonary artery catheterization	936 (10.6)
Renal replacement therapy	373 (4.2)
Intra-aortic balloon pump	331 (3.7)
Impella device	67 (0.8)
In-hospital mortality	1171 (13.2)
CICU LOS	2 (1–4)
Hospital LOS	8 (3–18)

Values are n (%), or median (interquartile range).

ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; ARNI, angiotensin receptor neprilysin inhibitor; ASA, acetylsalicylic acid (aspirin); BIPAP, bilevel positive airway pressure; BMI, body mass index; COPD, chronic obstructive pulmonary disease; ICU, intensive care unit; LOS, length of stay; MI, myocardial infarction; NSTEMI, non-ST segment myocardial infarction; OHCA, out-of-hospital cardiac arrest; PCI, percutaneous coronary intervention; SHS, Sinai Health System; STEMI, ST-elevation myocardial infarction; UHN, University Health Network.

Table 2. Admission diagnosis per year

Diagnosis	Total (N = 8865)	2014 (n = 1126)	2015 (n = 1253)	2016 (n = 1228)	2017 (n = 1353)	2018 (n = 1394)	2019 (n = 1340)	2020 (n = 1168)	P for trend	P for trend without 2020
STEMI	1373 (15.5)	173 (15.4)	183 (14.6)	207 (16.9)	233 (17.2)	195 (14.0)	217 (16.2)	165 (14.1)	0.548	0.792
NSTEMI	1488 (16.8)	213 (18.9)	230 (18.3)	203 (16.5)	221 (16.3)	222 (15.9)	208 (15.5)	191 (16.4)	0.014	0.006
Heart failure	1576 (17.8)	157 (13.9)	193 (15.4)	205 (16.7)	353 (26.1)	247 (17.7)	239 (17.8)	181 (15.5)	0.078	< 0.001
Arrythmia	1301 (14.7)	180 (16.0)	211 (16.8)	176 (14.3)	139 (10.3)	206 (14.8)	198 (14.8)	191 (16.4)	0.632	0.061
Postprocedural	1030 (11.6)	115 (10.2)	153 (12.2)	163 (13.3)	131 (9.7)	186 (13.3)	157 (11.7)	125 (10.7)	0.904	0.362
Pericardial disease	247 (2.8)	32 (2.8)	29 (2.3)	43 (3.5)	26 (1.9)	34 (2.4)	47 (3.5)	36 (3.1)	0.388	0.553
Other cardiac condition	616 (7.0)	75 (6.7)	100 (8.0)	81 (6.6)	85 (6.3)	94 (6.7)	92 (6.9)	89 (7.6)	0.885	0.597
Sepsis	315 (3.6)	42 (3.7)	37 (3.0)	47 (3.8)	38 (2.8)	60 (4.3)	45 (3.4)	46 (3.9)	0.470	0.733
Respiratory failure	390 (4.4)	65 (5.8)	42 (3.4)	48 (3.9)	55 (4.1)	61 (4.4)	59 (4.4)	60 (5.1)	0.758	0.557
Other noncardiac condition	529 (6.0)	74 (6.6)	76 (6.1)	55 (4.5)	72 (5.3)	89 (6.4)	78 (5.8)	84 (7.2)	0.352	0.804
OHCA	366 (4.1)	50 (4.4)	54 (.3)	57 (4.6)	47 (3.5)	64 (4.6)	59 (4.4)	35 (3.0)	0.195	0.938
Cardiogenic shock	1168 (13.2)	87 (7.7)	141 (11.3)	153 (12.5)	247 (18.3)	199 (14.3)	202 (15.1)	138 (11.8)	< 0.001	< 0.001
Overall noncardiac	1234 (13.9)	181 (16.1)	155 (12.4)	150 (12.2)	165 (12.2)	210 (15.1)	182 (13.6)	190 (16.3)	0.228	0.738

Values are n (%), unless otherwise indicated.
NSTEMI, non ST-segment elevation myocardial infarction; OHCA, out-of-hospital cardiac arrest; STEMI, ST-elevation myocardial infarction.

with CLABSI or ventilator-associated pneumonia), and ventilator-associated pneumonia (defined as development of pneumonia that develops after > 48 hours of mechanical ventilation) were also recorded, with a confirmatory bacterial culture result. The University Health Network research ethics board review committee approved this study.

Outcomes

Clinical outcomes were in-hospital mortality, CICU LOS, and hospital LOS. Patients were followed until discharge from the hospital. Hospital and CICU LOS were defined as the number of days that a patient remained in our local hospital or CICU. Therefore, the date of discharge to another centre was noted as the end of follow-up, although the patient could have been transferred to another ICU. Survival could not be ascertained in 1 patient (0.01%), and neither CICU nor hospital LOS was available for 4 patients (0.04%).

Statistical analysis

Categorical variables are shown as proportion (percentage) and were compared using the χ^2 test. The Shapiro-Wilk test showed that all continuous variables followed a non-normal distribution, and these are shown as median (interquartile range [IQR]), with differences between groups analyzed using the Mann-Whitney U test. To check for the temporal trends across years, a Mantel-Haenszel χ^2 test for linear trend was used for categorical variables, and a Spearman rank test was used for continuous variables. A sensitivity analysis was performed excluding patients admitted in 2020, as the CICU became a shared resource within the hospital during the COVID-19 pandemic. Covariates used for multivariate adjustment to see the effect of admission year were age, diagnosis at admission, CS, OHCA, smoking history, diabetes, previous PCI, bypass surgery, chronic kidney disease, peripheral vascular disease, congenital heart disease, chronic obstructive pulmonary disease, aspirin at admission, beta-blocker, angiotensin-converting enzyme inhibitor at admission, loop diuretics, statins, insulin, use of mechanical ventilation, vasopressors, pulmonary artery catheter, RRT, IABP, Impella, PCI during the admission, ventilation-associated pneumonia, sepsis, or CLABSI during the admission. We assessed independent predictors of prolonged CICU LOS and generated a model based on the presence of a CS, OHCA, noncardiac diagnosis, IMV, vasoactive drugs at admission, and admission diagnosis of HF, in which the presence of each of the variables increased the score by 1 point. To check for the effect of quality-improvement initiatives implemented during recent years on in-hospital mortality and CICU LOS, we did a multivariate analysis including the admission year and adjusting the odds ratio by the admission diagnosis, CS, OHCA or need for IMV, vasopressors or RRT. A 2-tailed P-value below 0.05 was considered significant for all comparisons. All analyses were performed with Stata 15.0 for Mac (StataCorp, College Station, TX).

Results

Baseline characteristics

During the study period, a total of 8865 consecutive CICU admissions occurred. The median age was 64.9 (53.2-76.1) years

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Table 3. Resource utilization according to diagnosis at admission

Resource	STEMI (n = 1373)	NSTEMI (n = 1488)	Heart failure (n = 1576)	Arrhythmia (n = 1301)	Postprocedural (n = 1030)	Pericardial (n = 247)	Other cardiac (n = 616)	Sepsis (n = 315)	Respiratory failure (n = 390)	Other noncardiac (n = 529)	Cardiac arrest (n = 366)	Cardiogenic shock (n = 1168)
PCI	825 (60.2)	513 (34.5)	41 (2.6)	30 (2.3)	14 (1.4)	0 (0.0)	5 (0.8)	2 (0.6)	1 (0.3)	11 (2.1)	74 (20.3)	131 (11.2)
Vasopressors	300 (21.9)	177 (11.9)	1021 (64.8)	154 (11.8)	103 (10.0)	12 (4.9)	148 (24.0)	164 (52.1)	136 (35.0)	140 (26.7)	231 (63.1)	1052 (90.1)
IMV	217 (15.8)	95 (6.4)	291 (18.5)	117 (9.0)	79 (7.7)	12 (4.9)	45 (7.3)	88 (27.9)	205 (52.6)	161 (30.7)	247 (67.5)	383 (32.8)
IABP	159 (11.6)	86 (5.8)	70 (4.4)	7 (0.5)	2 (0.2)	0 (0.0)	5 (0.8)	1 (0.3)	0 (0.0)	1 (0.2)	52 (14.2)	187 (16.0)
Impella	19 (1.4)	27 (1.8)	21 (1.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (1.1)	37 (3.2)
RRT	49 (3.6)	26 (1.8)	153 (9.7)	26 (2.0)	6 (0.6)	1 (0.4)	19 (3.1)	30 (9.5)	19 (4.9)	44 (8.4)	40 (10.9)	159 (13.6)
PAC	117 (8.6)	66 (4.5)	533 (34.0)	40 (3.1)	12 (1.2)	1 (0.4)	143 (23.3)	7 (2.2)	12 (3.1)	5 (1.0)	64 (17.5)	536 (46.1)
OHT or VAD	15 (1.1)	3 (0.2)	208 (13.2)	11 (0.9)	1 (0.1)	1 (0.4)	74 (12.0)	1 (0.6)	1 (0.3)	5 (1.0)	10 (2.7)	167 (14.3)
VAP	31 (2.3)	11 (0.7)	23 (1.5)	14 (1.1)	3 (0.3)	0 (0.0)	3 (0.5)	5 (1.6)	18 (4.6)	1 (0.2)	33 (9.0)	42 (3.6)
Sepsis	59 (4.3)	28 (1.9)	135 (8.6)	36 (2.8)	11 (1.1)	1 (0.4)	21 (3.4)	50 (15.9)	49 (12.6)	43 (8.2)	53 (14.5)	148 (12.7)
CICU LOS	1 (1-3)	2 (1-3)	4 (2-7)	2 (1-3)	1 (1-2)	2 (1-3)	1 (1-3)	2 (1-4)	3 (1-5)	2 (1-4)	3 (1-7)	5 (2-9)
Hospital LOS	4 (2-8)	7 (3-13)	17 (9-34)	7 (3-13)	4 (2-10)	7 (4-14)	14 (7-26)	15 (7-32)	21 (8-59)	13 (5-29)	11 (4-23)	16 (7-33)
Death during admission	182 (13.3)	103 (6.9)	343 (21.8)	70 (5.4)	24 (2.3)	27 (10.9)	60 (9.7)	105 (33.3)	125 (32.1)	132 (25.0)	155 (42.4)	369 (31.6)

Values are n (%) or median (interquartile range).

CICU, cardiac intensive care unit; IABP: intra aortic balloon pump; IMV, invasive mechanical ventilation; LOS, length of stay;. NSTEMI, non ST-segment elevation myocardial infarction; OHT, orthotopic heart transplantation; PAC, pulmonary artery catheter; PCI, percutaneous coronary intervention; RRT, renal replacement therapy; STEMI, ST-segment elevation myocardial infarction; VAD, ventricular assist device; VAP, ventilator-associated pneumonia.

(Table 1; Supplemental Table S1 for temporal trends during the study period), and 34.3% (n = 3195) were female. Most patients were referred from hospital wards (from within our institution or other hospitals, n = 4121; 46.5%) or other ICUs (n = 1428; 16.1%), whereas less than half were admitted from the emergency room at our hospital (n = 3299; 37.2%). Medical admissions accounted for 88.4% of admissions, and post-procedural monitoring (eg, percutaneous mitral valve repair, transcatheter aortic or pulmonary valve replacement) accounted for 11.6% of admissions. The most common primary cardiac diagnoses were ADHF (17.8%), NSTEMI (16.8%), STEMI (15.5%), and arrhythmias (14.7%). A secondary diagnosis of CS was found in 1168 patients (13.2%), and OHCA occurred in 366 patients (4.1%). Of those with a secondary diagnosis of CS, 923 (79.0%) had ADHF, 172 (14.7%) had a STEMI, and 67 (5.7%) had an NSTEMI. Of those with a secondary diagnosis of OHCA, 115 (31.4%) had a primary diagnosis of STEMI, 78 (22.1%) had a primary diagnosis of arrhythmia, 50 (13.7%) had ADHF, and 48 (13.1%) had respiratory failure. Noncardiovascular admission diagnosis accounted for 13.9% of the cases, including respiratory failure (4.4%) and sepsis (3.6%). Further data for the noncardiac admission can be found in Supplemental Table S2. The most common preexisting co-morbid conditions in the cohort were hypertension (49.0%), dyslipidemia (36.8%), heart failure (29.3%), diabetes mellitus (28.0%), atrial fibrillation (24.3%), chronic kidney disease (18.3%), and previous myocardial infarction (17.9%). A signif-icant temporal trend was found, toward admitting more females, more patients with chronic kidney disease and diabetes, more on chronic anticoagulation, and more with lower hemoglobin level at admission. The number of patients referred from other ICUs increased with time ($P < 0.001$, Supplemental Table S1). Over the period studied, the rates of admission for CS were higher ($P < 0.001$ for trend), and a trend was seen toward a higher admission rate for HF ($P = 0.074$, but < 0.001 if excluding 2020; Table 2).

Critical care resource utilization

In our cohort, 1310 patients (14.8%) required IMV with a median duration of 2 (1-5) days, with 39 patients (3.0% of those with IMV) failing a trial of ventilator liberation. Vaso-pressor or inotrope use was seen in 2355 (26.6%) of admis-sions, with 331 (3.7%) and 67 (0.8%) patients requiring an IABP or Impella device (Abiomed) for hemodynamic support, respectively, and 373 (4.2%) needing RRT. A PAC was used in 936 admitted patients (10.6%). Patients with HF and noncardiac conditions used more resources than the rest of admissions (Table 3), and patients admitted with a secondary diagnosis of CS utilized resources that included vasopressors or inotropes (90.1%), PAC monitoring (46.1%), IMV (32.8%), RRT (13.6%), IABP (16.0%), and Impella device (Abiomed; 3.2%). A trend occurred toward higher rates of vasopressor and inotrope use (20.3% vs 27.1% for 2014 and 2020; P for trend < 0.001), RRT (1.5% vs 7.5% for 2014 and 2020; P for trend < 0.001), and PAC use (9.1% vs 11.0% for 2014 and 2020; P for trend 0.024; Supplemental Table S3).

In-hospital mortality

In-hospital mortality of all CICU admissions was 13.2% (1171 patients). Patients with noncardiac conditions had
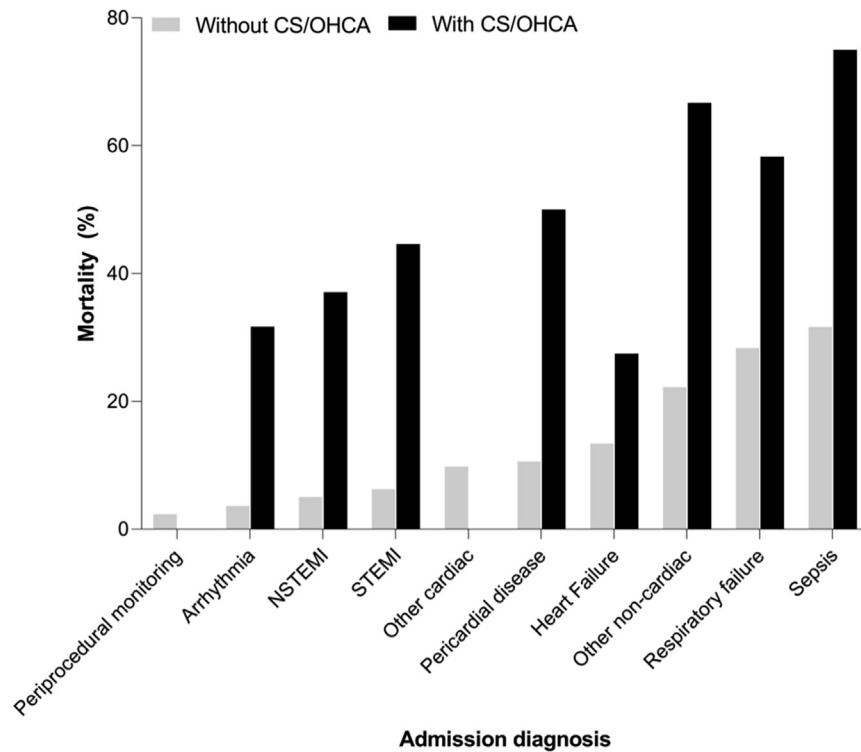
Figure 1. Mortality rates in patients admitted to the cardiac intensive care unit, per diagnosis at admission, depending on the presence or absence of cardiogenic shock (CS) or out-of-hospital cardiac arrest (OHCA). NSTEMI, non-ST-elevation myocardial infarction; STEMI, ST-elevation myocardial infarction.

higher mortality than those with cardiac issues (29.4% vs 10.6%, $P < 0.001$). Among patients admitted with a primary cardiac diagnosis, 13.3% of those with a STEMI died during the admission, as did 21.8% of those admitted with ADHF. The diagnoses of OHCA (42.4%) and CS (31.6%) were associated with the highest mortality. In the absence of CS or OHCA, death during admission occurred in 13.4% of ADHF patients, 6.2% of STEMI patients, 5.0% of NSTEMI patients, 3.6% of those with arrhythmic conditions, and 2.3% of patients requiring periprocedural monitoring (Fig. 1). Presenting with CS (adjusted odds ratio = 4.64, 95% confidence interval [CI] 3.72-5.79) or OHCA (adjusted odds ratio = 4.55, 95% CI 3.56-5.80) was associated with a higher mortality rate, as was developing sepsis during the admission (Fig. 2). All the interventions performed in the CICU were markers of poor prognosis, including IMV, use of vasopressors and inotropes, RRT, or mechanical circulatory support. Although crude mortality rates were similar across years, after accounting for the complexity of care, diagnosis at admission, and age, patients admitted in recent years had higher chances of survival (adjusted odds ratio for in-hospital mortality = 0.95 per year from 2014 to 2020, 95% CI 0.91-0.98). The decrease in mortality rate was especially significant in patients admitted for HF (P for trend = 0.012; see Supplemental Table S4 for the crude mortality rate according to the admission diagnosis).
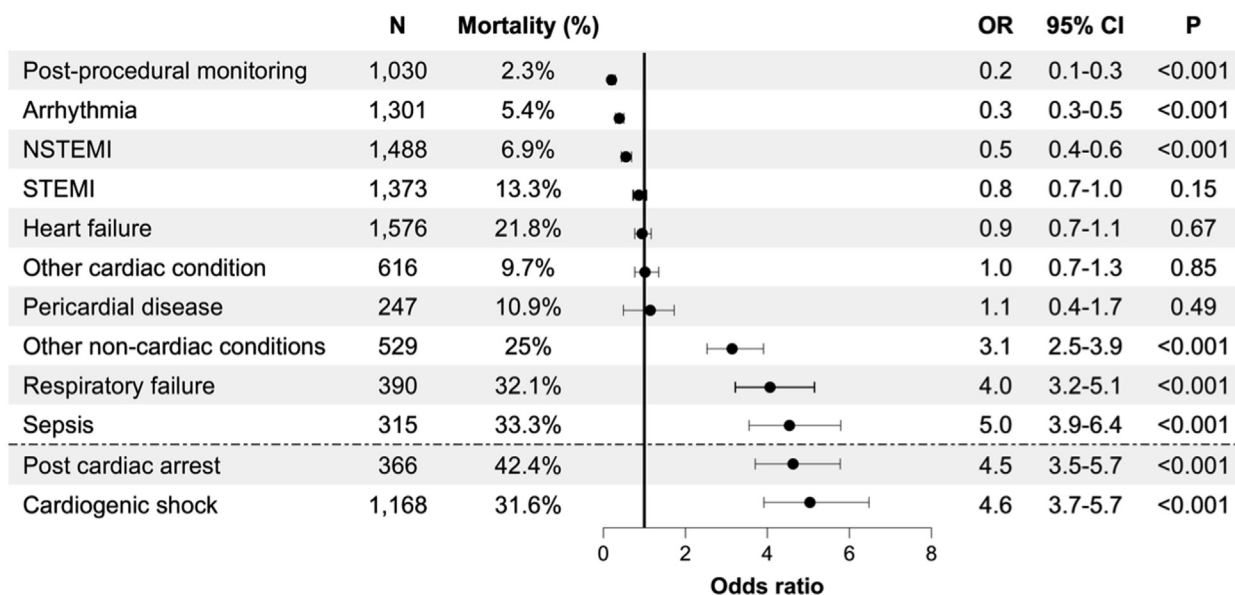
CICU and hospital LOS

Median LOS in the CICU was 2 (1-4) days, and median hospital LOS was 8 (3-18) days. Patients admitted with a primary diagnosis of ADHF (4 [2-7] days in CICU, 17 [9-34] days in the hospital), respiratory failure (3 [1-5] days in CICU, 21 [8-59] days in the hospital), and sepsis (2 [1-4] days in CICU, 15 [7-32] days in hospital) had a longer LOS compared to patients admitted with STEMI (1 [1-3] days in CICU, 4 [2-8] days in the hospital; $P < 0.001$ for all comparisons). Those with a secondary diagnosis of CS (5 [2-9] days,) or OHCA (3 [1-7] days,) also had a longer CICU LOS ($P < 0.001$ for both comparisons; Table 2). Using a 6-variable model, including noncardiac diagnosis, ADHF, CS, OHCA, IMV at admission, vasopressors, or inotropes at admission, it was seen that a score of > 2 was associated with a longer CICU stay (Fig. 3). Those with none of the variables had a median stay of 1 (0-2) day; those with 1 stayed for a median of 2 (1-4) days, and those with ≥ 2 stayed for 4 (2-8) days. The same trends were observed consistently in each of the years analyzed (Supplemental Fig. S1). The CICU LOS was shorter in the recent era (standardized β-coefficient for the regression = -0.025 per year, $P = 0.018$), a difference that was significant after adjustment for age, complexity of care, and diagnosis of admission (standardized β-coefficient = -0.043 per year, $P < 0.001$).

Discussion

In this study, we present data from 8865 admissions to a quaternary, academic care centre representative of a contemporary CICU. Our series is one of the largest single-centre registries and includes patients from 2019-2020, data for whom have not yet been reported in the literature. As in other

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	N	Mortality (%)		OR	95% CI	P
Post-procedural monitoring	1,030	2.3%		0.2	0.1-0.3	<0.001
Arrhythmia	1,301	5.4%		0.3	0.3-0.5	<0.001
NSTEMI	1,488	6.9%		0.5	0.4-0.6	<0.001
STEMI	1,373	13.3%		0.8	0.7-1.0	0.15
Heart failure	1,576	21.8%		0.9	0.7-1.1	0.67
Other cardiac condition	616	9.7%		1.0	0.7-1.3	0.85
Pericardial disease	247	10.9%		1.1	0.4-1.7	0.49
Other non-cardiac conditions	529	25%		3.1	2.5-3.9	<0.001
Respiratory failure	390	32.1%		4.0	3.2-5.1	<0.001
Sepsis	315	33.3%		5.0	3.9-6.4	<0.001
Post cardiac arrest	366	42.4%		4.5	3.5-5.7	<0.001
Cardiogenic shock	1,168	31.6%		4.6	3.7-5.7	<0.001

Odds ratio (x-axis: 0, 2, 4, 6, 8)

NSTEMI: non-ST elevation myocardial infarction; STEMI: ST-elevation myocardial infarction.

Figure 2. Adjusted odds ratio (OR) with 95% confidence interval (CI) for in-hospital mortality for each admission diagnosis, using as a comparator the average cardiac intensive care unit mortality in all-comers during the study period. NSTEMI, non-ST-elevation myocardial infarction; STEMI, ST-elevation myocardial infarction.

studies, a minority of patients are female, with a median age of 64.9 (53.2-76.1) years.[3-10] In our series, a significant proportion of patients were admitted with a cardiac diagnosis (86.1%), with a minority being admitted with a primary noncardiac diagnosis of respiratory failure (4.4%) or sepsis (3.6%). Our admission rates with a secondary diagnosis of CS were higher (13.2%) compared to those in other series (0.6%-10.9%),[3-5,9,10] and likely reflect our institution's role as a hub

Figure 3. Hospital length of stay (LOS): LOS in the cardiac intensive care unit (CICU) according to a score comprising a cumulative addition of markers of prolonged LOS (diagnosis of cardiogenic shock, out-of-hospital cardiac arrest, noncardiac condition, heart failure as main diagnosis, invasive mechanical ventilation, or use of vasopressors at admission). In the absence of any of these variables (score of 0), the median LOS in all-comers was 1 day.

site with referral pathways for CS management and advanced HF therapies. Using Canadian national healthcare data, Woolridge et al.[5] studied 373,992 patients admitted to CICUs across Canada, inclusive of academic (over two-thirds of the hospitals evaluated) and community sites, from 2005-2015. In comparison with our findings (2014-2020), the current dataset has lower rates of STEMI (15.5% vs 24.8%) and NSTEMI (16.6% vs 19.5%), and higher rates of ADHF (17.8% vs 8.4%), CS (13.4% vs 5.7%), and noncardiac admissions for sepsis (3.7% vs 1.7%) in comparison to the 2014-2015 cohort studied by Woolridge et al. (n = 70,014). Although the study by Woolridge et al. was inclusive of level-2 CICUs in the community setting, these CICUs comprised only approximately one-third of the hospitals evaluated. These findings suggest the ongoing evolution of admissions to the CICU, with higher acuity, increasing complexity with more critically ill cardiac patients, and as a result, higher rates of resource utilization. These findings are similar to those by Katz et al. who found higher admission rates of ADHF, CS, and sepsis, and lower rates of STEMI cases in their tertiary-level CICU from 1989-2006.[8]

In this registry, in-hospital mortality and CICU LOS is primary driven by those with ADHF, with or without CS, as well as those with noncardiac conditions. In-hospital mortality of all CICU admissions was 13.2% (1171 patients), which is similar to the percentage reported in the literature (4%-17.6%).[3-10] In one series by Jentzer et al., the authors found that in-hospital mortality (n = 10,004 patients) was higher in cardiac patients with multiple-organ failure in comparison to those with single-organ failure (22% vs 3%, adjusted OR = 3.02, 95% CI 2.47-3.68, $P < 0.001$). In addition, each subsequent failing organ system was associated with a higher risk of in-hospital mortality (OR = 1.93, 95% CI 1.74-2.14,
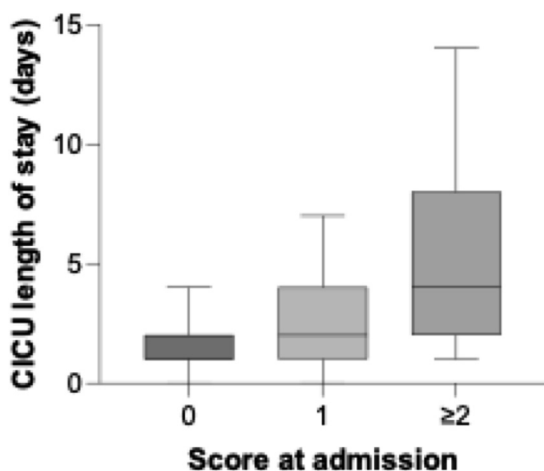
$P < 0.001$.[4] A second single-centre study (N = 1042 admissions) also found that those with acute respiratory failure (OR = 3.64, 95% CI 2.17-6.11) and acute kidney injury (OR = 1.85, 95% CI 1.15-2.98) had higher rates of in-hospital mortality.[3] Our findings corroborate what has been reported previously in the literature: noncardiovascular organ failure in the CICU is associated with a worse prognosis. These observed trends highlight the importance of formal advanced training in cardiac critical care. Novel staffing models to serve this population have been proposed in North America, including hiring CICU providers (both physicians and nursing teams) with expertise in mechanical circulatory support, target temperature monitoring, advanced modes of ventilation, invasive and noninvasive monitoring, and RRT.[11,12,14-16] As noncardiac critical illness including acute respiratory failure has morbidity rates of 20%-30%, and mortality rates of 40%-50%,[17] training pathways should also include training in palliative medicine and initiation of early discussions regarding goals of care. Effective communication with our patients and their loved ones remains a cornerstone of best practices within the critical care setting,[18-20] and integration in critical care training is encouraged.[21,22] Current pathways have been proposed that include combined advanced HF and transplant cardiology or interventional cardiology with critical care training or dual certification in cardiovascular and critical care medicine.[12,23-25]

Given the shift in patient profiles with respect to acuity of care and CICU resource allocation in patients presenting with CS, OHCA, and acute coronary syndrome with hemodynamic instability, patients with low resource-utilization rates and low mortality rates can be managed using different care models. These alternative pathways for care of lower-acuity patients with NSTEMI postrevascularization or STEMI postrevascularization without CS, or those admitted for postprocedure monitoring, could be developed and may include a short stay in the cardiac catheterization recovery room followed by a stay in a ward bed or a dedicated step-up unit. These models have been studied in the transaortic valve replacement population—100 highly selected patients were included in an accelerated recovery pathway directly to the ward postprocedure. The authors found minimal mortality and morbidity, and next-day discharge was achieved in 87%, with 97% of patients discharged within 2 days post-procedure.[26] This approach has been proposed for use in the uncomplicated STEMI population, for whom door-to-balloon time is short.[27] Same-day discharges also have been seen in select patients undergoing percutaneous mitral valve intervention, and care models can be developed to transition these low-risk patients out of the critical care setting.[28]

Limitations

This study has several limitations. This retrospective study was conducted at a single centre in a large, academic centre level-3 CICU. The findings in this series may be a result of local practice with uncontrolled confounders and are not necessarily applicable to other CICUs. In addition, we were unable to follow up with patients who were discharged to another institution, given that the registry was developed for quality-improvement purposes. Therefore, hospital LOS in patients who were transferred elsewhere was not fully accounted for based on the data available at our own institution. Also, at the time of inception of this retrospective registry, no standardization was performed, or recording of data to generate scores of disease severity—such as the **A**cute **P**hysiology **a**nd **C**hronic **H**ealth **E**valuation (APACHE), **Or**ganization to **A**ssess **S**trategies in **I**schemic **S**yndromes (OASIS), or Sequential Organ Failure Assessment (SOFA) scores—or data to calculate ICU-related admission risk score. Given the nature of the registry, futher details including surgical procedures also were not recorded.

Conclusions

In this analysis of 8865 patients admitted to a contemporary academic quaternary centre CICU, trends were found of higher acuity of patients with critical cardiac and noncardiac illness, and higher use of critical care resources. Resource utilization and allocation should be focused on developing alternative pathways for patients who have lower-acuity cardiac disease. Education streams for cardiologists currently are available for additional critical care training, including greater competency in treating noncardiac comorbid illnesses and providing end-of-life care. Given the rapid rise in the complexity of patients admitted to modern CICUs, the development of cardiac critical care fellowship programs is crucial to support this growing population.

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Disclosures

The authors have no conflicts of interest to disclose.

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Supplementary Material

To access the supplementary material accompanying this article, visit *CJC Open* at https://www.cjcopen.ca/ and at https://doi.org/10.1016/j.cjco.2022.06.004.