Hindawi
Journal of Cardiac Surgery
Volume 2024, Article ID 3325296, 8 pages
https://doi.org/10.1155/2024/3325296

Research Article

Factors Influencing Pain Scores and Opioid Demand after Robotically Assisted Cardiac Surgery

Irsa Hasan,[1] **Laura Seese**,[1] **Rachel Deitz**,[1] **Faaz Ashraf**,[1] **Takuya Ogami**,[1] **Kathirvel Subramaniam**,[2] **Michael Boisen**,[2] **Pyongsoo Yoon**,[1,3] **David West**,[1,3] **David Kaczorowski**,[1,3] **Ibrahim Sultan**,[1,3] **and Johannes Bonatti**[1,3]

[1]*Department of Cardiothoracic Surgery, University of Pittsburgh Medical Center, Pittsburgh, PA, USA*
[2]*Department of Anesthesiology and Perioperative Medicine, University of Pittsburgh School of Medicine, Pittsburgh, PA, USA*
[3]*Heart and Vascular Institute, University of Pittsburgh Medical Center, Pittsburgh, PA, USA*

Correspondence should be addressed to Johannes Bonatti; bonattijo@upmc.edu

Received 18 November 2023; Accepted 26 March 2024; Published 17 April 2024

Academic Editor: Oktay Korun

Objective. Introduction of minimally invasive cardiac surgery anticipated the reduction in postoperative pain but little quantitative data are available on this effect. This study investigated factors influencing pain scores and opioid demand after robotically assisted cardiac procedures. *Methods*. Using data derived from prospective robotic cardiac surgery and anesthesia databases, we analyzed 75 patients undergoing robotic cardiac surgery between July 2021 and December 2022. Study endpoints were mean cumulative pain scores measured on a 0–10 scale and opioid use on postoperative days (PODs) 1 to 4. Pain scores and oral morphine equivalent (OME) were correlated with perioperative variables. *Results*. Postoperatively, 39/75 (52%) of patients were extubated in the operating room (OR) and 34/75 (45.3%) were extubated within 24 hours of surgery. Mean pain scores declined from 5.8 (SD 1.5) on POD 1 to 3.8 (SD 1.6) on POD 4 and OME fell from 34.9 (SD 29) mg to 8.2 (SD 11.8) mg. OME use correlated significantly with pain scores ($p < 0.01$). Higher pain scores on postoperative day (POD) 1 were associated with diabetes ($p = 0.006$), tobacco use ($p = 0.006$), and extubation in the OR ($p = 0.017$). Opioid utilization was higher in younger patients ($p < 0.001$), heavier patients ($p = 0.033$), active tobacco users ($p = 0.01$), longer procedure times ($p = 0.002$), and those extubated in the OR ($p < 0.001$). *Conclusion*. Pain and opioid consumption after robotically assisted cardiac surgery are moderate but decline steadily within the first four postoperative days. Tobacco use and extubation in the OR were associated with increased pain and opioid consumption.

1. Background

Compared to its counterparts in abdominal and thoracic surgery disciplines, adoption of robotic surgery for cardiac procedures has been relatively slow to gain popularity. A minimally invasive surgical approach is often associated with less pain postoperatively, improved respiratory function, shorter hospitalization, and faster recovery. However, few studies have demonstrated clear and consistent benefit of robotic cardiac surgery compared to traditional sternotomy concerning pain [1].

The course of pain scores has been described for classic heart surgery but not for robotic cardiac surgery [2]. Known factors that are associated with increased pain after traditional cardiac surgery are female gender, young age, and use of cardiopulmonary bypass [3, 4]. Data on factors that influence pain after robotic cardiac surgery are lacking. This study therefore describes trends in postoperative pain scores and opioid utilization across various robotic cardiac surgery procedures and analyzes perioperative factors contributing to pain.

2. Methods

This study was approved by the Institutional Review Board (IRB #21080141).

2.1. Patients and Data Collection. Data for patients undergoing robotic-assisted cardiac surgery were derived from prospectively maintained surgery and anesthesia databases. Between July 2021 and December 2022, 76 patients underwent robotic-assisted cardiac surgery. One patient underwent robotic-assisted epicardial lead placement and was excluded in this analysis. The remaining procedures included robotic mitral valve repair (MVr, $n = 32$), minimally invasive direct coronary artery bypass (MIDCAB, $n = 9$), and totally endoscopic coronary bypass grafting (TECAB, $n = 18$). Of the 75 included patients, no patients had chronic preoperative pain. Baseline patient characteristics and intraoperative and postoperative data are reported in Table 1.

2.2. Anesthetic Considerations. A standard analgesic protocol was utilized for patients undergoing robotic cardiac surgery consisting of (1) preoperative thoracic paravertebral block at T4 with 20 mL ropivacaine 0.2%; (2) acetaminophen scheduled every 6 hours (intravenous, then oral when able); (3) intraoperative analgesia with low-dose fentanyl; and (4) postoperative analgesia with intravenous hydromorphone and oral oxycodone. Ketorolac may be used starting on postoperative day #1 in case of normal kidney function. Patient-controlled analgesia (PCA) was not used.

Endpoints of this retrospective study were mean cumulative pain scores measured on a 0–10 scale and opioid use on postoperative days (PODs) 1 to 4. Opioid utilization during this time was converted to oral morphine equivalents (OMEs) [5]. All patient-reported pain scores entered into the electronic medical record system were collected.

2.3. Statistical Analysis. Statistical analysis was conducted using SPSS Statistics, version 28.0.1.1. Patient-reported pain scores and OMEs were correlated with preoperative and intraoperative variables. Categorical variables are shown as absolute values and percentages and continuous variables are shown as means and standard deviations (SDs). Correlations were calculated using Pearson's correlation coefficient. Differences between groups were calculated using Student's *t*-test and one-way ANOVA. Time-related measures of pain scores and OME were assessed using ANOVA for repeated measures. p value < 0.05 was considered statistically significant.

3. Results

Preoperative and intraoperative variables are depicted in Tables 1 and 2. The mean age was 62 (SD 10.1) years, 71% (53/75) were male, and mean STS risk of mortality was 0.65% (SD 0.62). Postoperatively, 39/75 (52%) of patients were extubated in the operating room, 34/75 (45.3%) were extubated within 24 hours of surgery, 1/75 (1.3%) was extubated within 72 hours, and 1/75 (1.3%) required ventilation beyond 72 hours. One patient who was extubated in the OR required reintubation for an additional 12 hours.

Mean pain scores declined from 5.8 (SD 1.5) on POD 1 to 3.8 (SD 1.6) on POD 4 ($p < 0.001$), Figure 1(a). OME fell from 34.9 (SD 29) mg on the first postoperative day to 8.2 (SD 11.8) mg on the fourth postoperative day, Figure 1(b). As shown in Figure 2, the highest pain scores on POD 1 were seen in robotically assisted MIDCAB followed by robotic secundum ASD and myxoma resection. The lowest pain score was noted for robotic mitral valve repair. Opioid requirements were not significantly different among procedure types, Figure 2.

Mean pain scores on POD 1 were higher in patients with diabetes ($p = 0.005$), in those with tobacco use ($p = 0.006$), and those extubated in the OR ($p = 0.017$), Table 3. Pain score on the first postoperative day was associated with higher pre-op hemoglobin A1c levels ($p = 0.031$) and was negatively correlated with shorter myocardial ischemia time ($p = 0.044$), Figure 3.

Opioid utilization showed a strong negative correlation with age ($p < 0.001$), while OME demand was higher in heavier patients ($p = 0.033$) and current smokers ($p = 0.01$), Figure 4 and Table 3. A longer procedure time and extubation in the operating room were intraoperative factors associated with increased opioid demand ($p = 0.002$ and $p < 0.001$, respectively), Table 4.

The strong positive correlation of pain score on POD 1 with opioid consumption ($p < 0.001$) is depicted in Figure 5. Factors including gender, New York Heart Failure class, lung disease, preoperative creatinine, diabetes mellitus, hypertension, mini-thoracotomy approach, conversion to sternotomy, and total incision length did not influence pain scores or OME use. Additionally, preoperative lab values of white blood cell count, albumin level, and platelet count did not impact pain scores or OME utilization.

No signifciant correlation was found between mean pain scores and OMEs with postoperative hospital length of stay (p value 0.294 and 0.096, respectively).

4. Discussion

The present study demonstrates that mean postoperative pain scores after robotically assisted cardiac surgery reach a moderate level and decrease by 35% on the fourth postoperative day. Opioid demand on postoperative day one reaches an average of 35 mg and decreases by 77% on postoperative day four. Several perioperative factors such as tobacco use and extubation in the operating room strongly influence both the level of pain and opioid demand in this study.

Adequate pain control is emphasized in our current practice. Pain studies often report pain peaking at POD 2 and associated with a variety of baseline characteristics such as gender, body mass index, and smoking [6, 7]. Previous data suggest that improvements in postoperative outcomes can be further enhanced by preoperative optimization of physical rehabilitation, smoking cessation, and comorbidity management.

4.1. Pain Scores. Generally, the course of pain reduction within the first four postoperative days can be regarded as relatively slow. Andrade and coworkers described a decrease

Table 1: Preoperative patient characteristics.

Age (mean)	62.1 (SD 10.1)
Gender = male, *n* (%)	53/75 (71%)
Height, cm (mean)	174 (SD 9.8)
Weight, kg (mean)	82 + 18.1
Body mass index (mean)	27 + 4.6
Hypertension, *n* (%)	54/75 (72%)
Diabetes mellitus, *n* (%)	14/75 (19%)
New York Heart Association Stage, *n* (%)	
1	23/75 (31%)
2	27/75 (36%)
3	19/75 (25%)
4	6/75 (8%)
Smoking history, *n* (%)	
Never smoker	43 (57%)
Current smoker	10 (13%)
Former smoker	22 (29%)
COPD, *n* (%)	14/75 (81%)
FEV1, % (mean)	101.3% (SD 15.3)
DLCO, % (mean)	99.1% (SD 19.3)
Obstructive sleep apnea, *n* (%)	13/75 (17%)
Bronchodilator use, *n* (%)	7/75 (9.3%)
Preoperative left ventricular ejection fraction, % (mean)	57.8 ± 9.1%
Cerebrovascular disease, *n* (%)	7/75 (9.3%)
Peripheral vascular disease, *n* (%)	0/75 (0%)
Liver dysfunction (any), *n* (%)	1/75 (1.3%)
Preoperative dialysis need, *n* (%)	1/75 (1.3%)

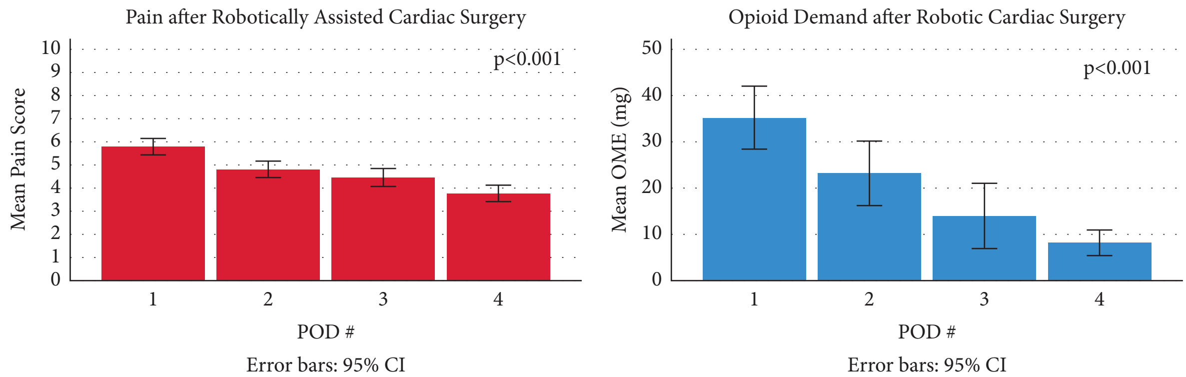
Table 2: Intraoperative variables.

Procedure type, *n* (%)	
MIDCAB	11 (15%)
MVR	37 (49%)
MVR/TVR	1 (1%)
Myxoma	1 (1%)
ASD	2 (3%)
TECAB	23 (31%)
Total procedure time, minutes (mean)	307.9 ± 76.5
Cardiopulmonary bypass time, minutes (mean)	118.1 + 55.7
Cross-clamp time, minutes (mean)	82.5 + 45.7
Conversion to sternotomy, *n* (%)	4/75 (5.3%)
Total incision length, cm (mean) (including all ports, mini-thoracotomy, sternotomy cannulation site)	17.3 + 4.9
Extubation in operating room, *n* (%)	39/75 (52%)
Revision for bleeding, *n* (%)	1/75 (1.3%)
Stroke, *n* (%)	0/75 (0%)
Mortality, *n* (%)	0/75 (0%)

SD: standard deviation.

of postoperative pain in cardiac surgery performed through sternotomy from 2.6 to 1.3 on a one to five level scale during the first four postoperative days, a 50% reduction [2]. Pain in this analysis was in most instances described as moderate in the initial few postoperative days. We found that mean pain scores declined from 5.8 on POD 0 to 3.8 on POD 4 ($p < 0.001$), a 35% reduction. This difference between Andrade et al.'s results and ours could be due to the higher pain associated with thoracotomy incisions.

Specifically in this study, the patients undergoing robotic-assisted MIDCAB reported statistically significant higher pain scores. The thoracic mini-incision in the MIDCAB procedure was described as specifically painful since the introduction of the procedure in the mid-1990s [7]. The damage or trauma to the intercostal nerve from an incision involving rib spreading can be particularly painful [3]. Walther et al. describe that the pain from a lateral thoracotomy is significant in the postoperative period; it typically peaks around day 3 without significant differences in pain outcomes compared to traditional sternotomy by POD 7 [7]. Although robotic-assisted mitral valve surgery also involves a mini-thoracotomy, the combination of a mini-thoracotomy with internal mammary artery harvesting may contribute to increased inflammation and pain



(a) (b)

FIGURE 1: (a) Mean pain scores after robotic-assisted cardiac surgery based on postoperative day (POD). (b) Mean opioid demand (measured as oral morphine equivalence, OME) after robotic-assisted cardiac surgery based on postoperative day (POD).

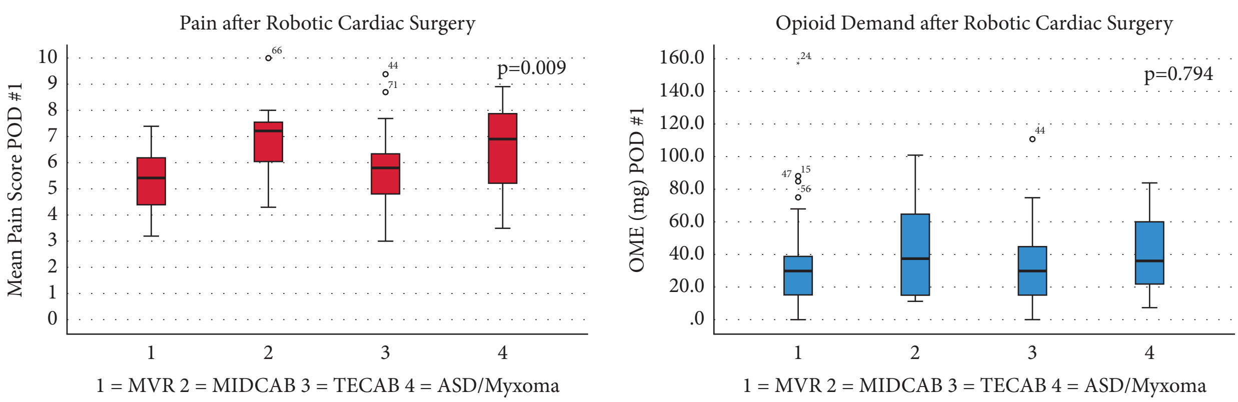


FIGURE 2: Mean pain score and opioid demand by procedure type.

noted in the MIDCAB procedure [8]. Notably, in our practice, intercostal sutures are placed for all mini-thoracotomies to help alleviate early postoperative pain and intercostal nerve blocks are performed [9].

Patients with elevated hemoglobin A1c levels more often underwent robotic-assisted MIDCAB rather than TECAB in this study. This may explain the higher level of pain in found in this diabetic patient population. Additionally, the association of shorter myocardial ischemic times with higher pain scores may be due to the predominance of MIDCABs, in which the procedure is carried out on the beating heart.

The enhanced recovery pathway aims to achieve extubation within the first six hours. Studies comparing extubation in the operating room after cardiac surgery compared to the intensive care unit have shown higher reintubation rates and bleeding but lower resource utilization [10, 11]. When comparing pain intensity and analgesia use, Lin et al. found no significant differences between early extubation in sternotomy and thoracotomy incisions in cardiac surgery [12]. However, in this study, patients who were able to be extubated in the operating room at the completion of the procedure reported higher pain scores on POD 1 than those that were extubated in the intensive care unit. Extubation in the OR being associated with higher opioid requirements is most likely a result of earlier withdrawal of sedation and anesthesia. Additionally, after early extubation, patients may have also been able to express their pain to nursing staff and physicians, leading to higher opioid administration.

Multiple studies have demonstrated significant pain associated with coughing, movements, turning around, getting up from bed, and deep breathing [3]. Our results support higher pain and opioid use in patients with recent or active smoking history, which causes increased coughing, atelectasis, and mucus production.

Interestingly, conversion to sternotomy was not associated with increased pain or narcotic use. This may be explained by the known fact that sternotomy is less painful than lateral thoracotomy and the added trauma may not have played a major role. As there was not even a trend towards increased pain with conversion, it will have to be seen if larger patient numbers can demonstrate an influence.

4.2. Opioid Demand. OME requirements in various robotic procedures did not differ significantly but followed a similar pattern as pain scores. There was a very strong negative correlation between narcotic pain medication demand and

Table 3: Univariate correlation of preoperative patient characteristics with pain scores and opioid demand on postoperative day 1.

Variable	Correlation mean pain score	p value	Correlation mean OME demand	p value
Age	−0.027	0.818	−0.383	<0.001
Height	0.069	0.557	0.216	0.062
Weight	0.147	0.210	0.246	0.033
Body mass index	0.14	0.230	0.178	0.126
Hemoglobin A1c	0.25	0.031	−1.21	0.30
Preoperative creatinine	−0.118	0.315	0.049	0.679
FEV1% of predicted	−0.158	0.175	−0.007	0.952
DLCO% of predicted	−0.80	0.497	−0.004	0.972
STS risk of mortality	0.02	0.865	−0.146	0.211
Left ventricular ejection fraction	−0.13	0.28	0.004	0.97
	Mean pain score	p value	Mean OME demand	p value
Gender		0.487		0.060
Male	5.8 (SD 1.5)		38.8 (SD 32.5)	
Female	5.6 (SD 1.5)		25.3 (SD 15)	
Diabetes		0.005		0.706
No	5.5 (SD 1.3)		34.3 (SD 28.6)	
Yes	6.7 (SD 1.8)		37.6 (SD 31.7)	
Hypertension		0.883		0.319
No	5.8 (SD 1.3)		40.3 (SD 32.7)	
Yes	5.6 (SD 1.4)		32.8 (SD 25.4)	
Smoking history		0.006		0.010
Never smoker	5.3 (SD 1.4)		28.3 (SD 22.3)	
Former smoker	6.2 (SD 1.1)		29.3 (SD 22.7)	
Current smoker	6.5 (SD 1.5)		50.3 (SD 37.5)	
Chronic obstructive pulmonary disease		0.178		0.092
No	5.8 (SD 1.5)		37.6 (SD 30.1)	
Yes	5.3 (SD 1.6)		23.1 (SD 20.6)	
Cerebrovascular disease		0.085		0.371
No	5.6 (SD 1.3)		34.1 (SD 27.5)	
Yes	6.6 (SD 2.6)		44.6 (SD 44.1)	
New York Heart Failure Symptoms		0.140		0.301
I	5.2 (SD 1.6)		29.9 (SD 19.6)	
II	5.9 (SD 1.5)		39.8 (SD 35.2)	
III	5.8 (SD 1.3)		29.2 (SD 28.7)	
IV	6.7 (SD 0.8)		49.5 (SD 27.2)	

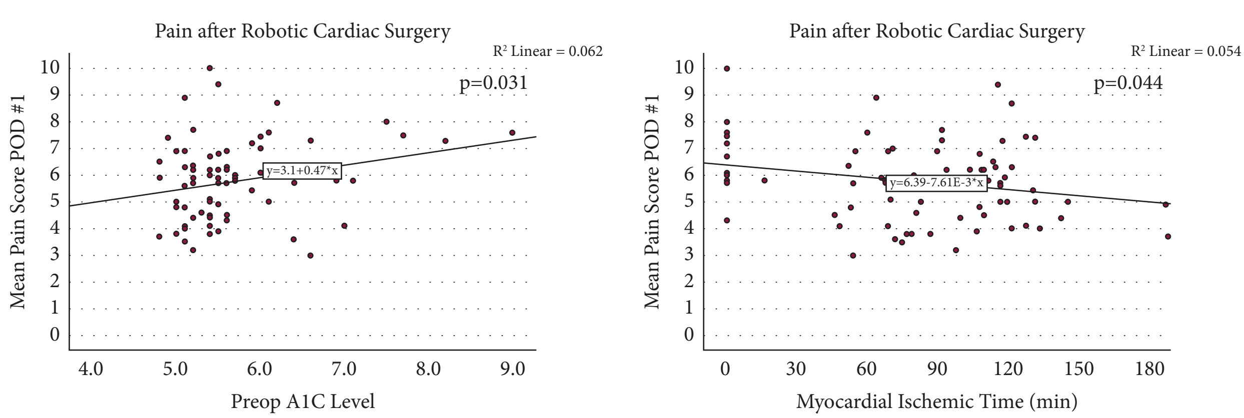


Figure 3: Mean pain score on postoperative day (POD) 1 based on preoperative hemoglobin A1c level and myocardial ischemic time.

age. Younger patients required morphine equivalents in the 40 to 60 mg range, whereas older patients asked for less than 20 mg on postoperative day one. Data in the literature show that age is a significant factor influencing the perception of pain after heart surgery [3, 13, 14].

It has been previously reported that women report a higher pain intensity than men after heart surgery [13, 15, 16]. In our analysis, interestingly, men had a higher opioid demand than women by approximately 13 mg, but the difference did not reach statistical significance.

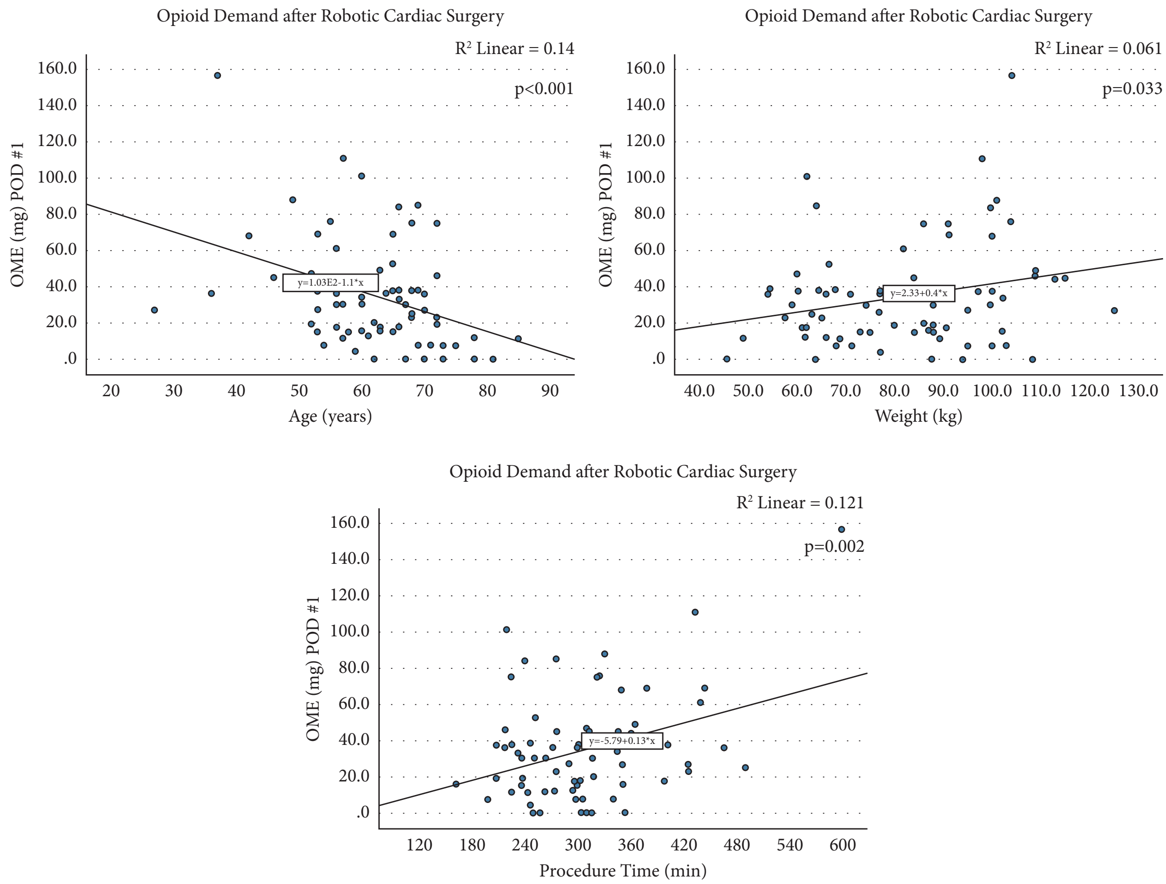


Figure 4: Opioid demand on postoperative day (POD) 1 based on factors of age, weight, and procedure time.

Table 4: Univariate correlation of intraoperative variables with pain scores and opioid demand on postoperative day 1.

Variable	Correlation mean pain score	p value	Correlation mean OME demand	p value
Cardiopulmonary bypass time	0.118	0.311	0.970	0.409
Myocardial ischemic time	−0.233	0.044	0	0.999
Procedure time	0.174	0.135	0.348	0.002
Total incision length	−0.082	0.484	0.077	0.512
	Mean pain score	p value	Mean OME demand	p value
Conversion to larger incision		0.652		0.316
No	5.8 (SD 1.5)		35.7 (SD 29.4)	
Yes	5.4 (SD 0.9)		20.6 (SD 19.8)	
Extubation in the operating room		0.017		<0.001
No	5.2 (SD 1.1)		19.5 (SD 17.8)	
Yes	6.0 (SD 1.6)		44.6 (SD 30.6)	

Although previous studies have found higher pain with increasing body mass index [17], our study did not demonstrate a statistical significance between these factors. However, we did find OME requirements significantly increased with body weight. This can probably be explained by the simple fact that pain medication dosage is calculated according to body weight.

We found a very strong correlation between procedure time and opioid demand. This is in line with data presented by Mazzeffi and Khelemsky which demonstrate an association of postoperative pain and duration of surgery [18].

4.3. Factors Influencing Both Pain Scores and Opioid Demand. The two factors that strongly influenced both the level of pain on the first postoperative day and the corresponding demand for narcotic pain medication were extubation in the operating room and a history of smoking. Patients extubated in the OR had an average pain level of 6 as compared to a level of 5 in patients extubated in the ICU; additionally, the early extubation group required more than twice the dose of morphine equivalents. Current smokers also showed POD 1 pain scores of 6 as compared to a score of

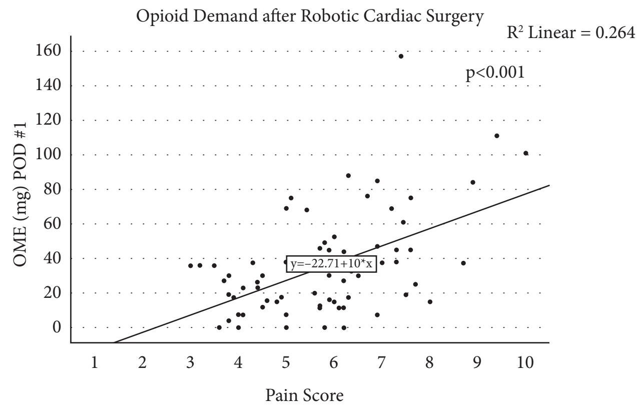


Figure 5: Correlation of opioid utilization and pain score on postoperative day (POD) 1.

5 in nonsmokers, and they required more than 20 mg more opioid medication.

Extubation in the operating room may not allow for enough time to fully recruit the lungs after single lung ventilation. These patients, especially if they are smokers, may exhibit more atelectasis and frequent coughing, leading to higher pain levels postoperatively. A prospective study in 705 patients undergoing traditional cardiac surgery clearly demonstrated that the most severe postoperative pain was associated with coughing and movement [19].

The present study is one of the few in the literature demonstrating this pain difference in early extubation and smokers. Despite our efforts with enhanced recovery protocols and decreasing length of stay with early extubation, this finding is important in managing postoperative pain and pulmonary rehabilitation. Perhaps, patients with a smoking history would not benefit from early extubation, but further investigation is needed. Although there is increased pain in the patients who undergo extubation in the operating room, it is worth considering that this avoids patients remembering waking up with an endotracheal tube, as this can be considered an uncomfortable experience.

4.4. Importance of Appropriate Pain Management after Cardiac Surgery. It has also been demonstrated that initial postoperative pain severity has been associated with persistent pain [8, 15], which stresses the importance in management of acute pain in the first few days after surgery. A meta-analysis of 23 studies found that up to 37% reported persistent postoperative pain at 6 months after cardiac surgery and up to 17% at 2 years [4]. Furthermore, new persistent pain and opioid use after cardiac surgery were found to be dependent on opioid prescription size at the time of discharge [20].

Data from the Mayo Clinic did not demonstrate a significant difference in postoperative pain between traditional sternotomy and robotic approach for mitral valve repair but found earlier return to work and improved quality of life [1]. Less chest pain frequency was reported within the first year using surveys, but the difference was indistinguishable after 1 year.

The national attention to the opioid epidemic has highlighted the importance of pain management in surgical practice. Holst et al. demonstrated significant variation in opioid prescribing guidelines, thus urging the importance of standardization of pain regimen [21]. When compared to thoracotomy, patients after robotic-assisted cardiac surgery were less likely to require opioid refills [21]. However, pain differences were not significantly evident between the robotic-assisted method and partial sternotomy and sternotomy. The pain management in our institution encourages less use of narcotic pain medication and increased prescription of alternatives such as acetaminophen, ketorolac, ibuprofen, and gabapentin. The 77% decrease in opioid consumption on the fourth postoperative day is an encouraging finding in this study. By comparison, Balkhy and coworkers found 80% free of opioids within one week after robotic cardiac surgery [22].

4.5. Study Limitations. This is a small retrospective study in a relatively inhomogeneous group of patients undergoing the spectrum of robotic cardiac surgery. Although procedure type did not influence pain scores and opioid utilization, comparing pain across multiple procedures is a limitation of this study. Due to the size of the study population, we carried out univariate analysis and multivariate analysis was not performed but will be carried out in future studies. Propensity-matched comparative studies and randomized comparisons with cardiac surgery through sternotomy are warranted. We collected pain score data points from electronic medical records, which were recorded at the discretion of nursing staff. Nursing staff are instructed to record pain scores at every shift but there is potential bias where patients with more pain were more frequently asked to rate their pain score. Study limitations also include the inability to assess psychosocial aspects that can contribute to pain. Preoperative expectation of pain is notably an important determinant of postoperative pain perception but was not a focus of this study.

5. Conclusion

As robotic-assisted techniques become more common in cardiac surgery, it is important to understand that this minimally invasive alternative does not necessarily translate into minimal pain as patients may expect. In this study, pain was found to be moderate after robotic-assisted cardiac surgery but significantly declined within the first 4 postoperative days. Pain scores and opioid consumption correlated. Higher pain scores were found in the MIDCAB group compared to other procedures. Factors influencing both higher pain scores and opioid consumption were smoking and extubation in the operating room. Additionally, young patients and longer procedure times required more opioids. As we delineate factors influencing pain, patient perception and counseling can be optimized in anticipation of robotic cardiac procedures.

Data Availability

The patient data used to support the findings of this study are available from the corresponding author upon request.

Disclosure

The abstract was submitted and presented at the International Society of Minimally Invasive Cardiac Surgery Annual Conference in June 2023 (https://meetings.ismics.org/program/2023/PC68.cgi#:~:text=This20study20delineates20patient20factorsconsumption20following20robotic20cardiac20procedures).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] R. M. Suri, R. M. Antiel, H. M. Burkhart et al., "Quality of life after early mitral valve repair using conventional and robotic approaches," *The Annals of Thoracic Surgery*, vol. 93, no. 3, pp. 761–769, 2012.

[2] E. V. Andrade, M. H. Barbosa, and E. Barichello, "Avaliação da dor em pós-operatório de cirurgia cardíaca," *Acta Paulista de Enfermagem*, vol. 23, no. 2, pp. 224–229, 2010.

[3] M. Zubrzycki, A. Liebold, C. Skrabal et al., "Assessment and pathophysiology of pain in cardiac surgery," *Journal of Pain Research*, vol. 11, pp. 1599–1611, 2018.

[4] L. Guimarães-Pereira, P. Reis, F. Abelha, L. F. Azevedo, and J. M. Castro-Lopes, "Persistent postoperative pain after cardiac surgery: a systematic review with meta-analysis regarding incidence and pain intensity," *Pain*, vol. 158, no. 10, pp. 1869–1885, 2017.

[5] Centers for Medicare and Medicaid Services, "Opioid morphine equivalent conversion factors," https://www.cms.gov/Medicare/Prescription-Drug-Coverage/PrescriptionDrugCovContra/Downloads/Opioid-Morphine-EQ-Conversion-Factors-March-2015.pdf.

[6] J. Gohari, L. Grosman-Rimon, M. Arazi et al., "Clinical factors and pre-surgical depression scores predict pain intensity in cardiac surgery patients," *BMC Anesthesiology*, vol. 22, no. 1, p. 204, 2022.

[7] T. Walther, V. Falk, S. Metz et al., "Pain and quality of life after minimally invasive versus conventional cardiac surgery," *The Annals of Thoracic Surgery*, vol. 67, no. 6, pp. 1643–1647, 1999.

[8] P. Lahtinen, H. Kokki, and M. Hynynen, "Pain after cardiac surgery," *Anesthesiology*, vol. 105, no. 4, pp. 794–800, 2006.

[9] A. M. Allama, "Intercostal muscle flap for decreasing pain after thoracotomy: a prospective randomized trial," *The Annals of Thoracic Surgery*, vol. 89, no. 1, pp. 195–199, 2010.

[10] A. D. Hawkins, R. J. Strobel, J. H. Mehaffey et al., "Operating room versus intensive care unit extubation within 6 hours after on-pump cardiac surgery: early results and hospital costs," *Seminars in Thoracic and Cardiovascular Surgery*, vol. 679, no. 22, pp. 272–6, 2022.

[11] S. L. Camp, S. C. Stamou, R. M. Stiegel et al., "Quality improvement program increases early tracheal extubation rate and decreases pulmonary complications and resource utilization after cardiac surgery," *Journal of Cardiac Surgery*, vol. 24, no. 4, pp. 414–423, 2009.

[12] T. Y. Lin, K. M. Chiu, C. W. Lu, W. H. Jean, M. J. Wang, and S. H. Chu, "Immediate extubation in the operating room after cardiac operations with thoracotomy and sternotomy," *Acta Anaesthesiologica Taiwanica*, vol. 45, no. 1, pp. 3–8, 2007.

[13] X. M. Mueller, F. Tinguely, H. T. Tevaearai, J. P. Revelly, R. Chioléro, and L. K. von Segesser, "Pain location, distribution, and intensity after cardiac surgery," *Chest*, vol. 118, no. 2, pp. 391–396, 2000.

[14] A. Shaw and F. J. Keefe, "Genetic and environmental determinants of postthoracotomy pain syndrome," *Current Opinion in Anaesthesiology*, vol. 21, no. 1, pp. 8–11, 2008.

[15] E. Kalso, S. Mennander, T. Tasmuth, and E. Nilsson, "Chronic post-sternotomy pain," *Acta Anaesthesiologica Scandinavica*, vol. 45, no. 8, pp. 935–939, 2001.

[16] H. J. Gerbershagen, E. Pogatzki-Zahn, S. Aduckathil et al., "Procedure- specific risk factor analysis for the development of severe postoperative pain," *Anesthesiology*, vol. 120, no. 5, pp. 1237–1245, 2014.

[17] S. Micah, R. Barolia, Y. Parpio, S. Kumar, and H. Sharif, "Factors associated with postoperative pain among patients after cardiac surgery in the tertiary care teaching hospital of Karachi, Pakistan," *Pain Research and Treatment*, vol. 2019, Article ID 9657109, 8 pages, 2019.

[18] M. Mazzeffi and Y. Khelemsky, "Poststernotomy pain: a clinical review," *Journal of Cardiothoracic and Vascular Anesthesia*, vol. 25, no. 6, pp. 1163–1178, 2011.

[19] L. B. Milgrom, J. A. Brooks, R. Qi, K. Bunnell, S. Wuestefeld, and D. Beckman, "Pain levels experienced with activities after cardiac surgery," *American Journal of Critical Care*, vol. 13, no. 2, pp. 116–125, 2004.

[20] A. A. Brescia, J. F. Waljee, H. M. Hu et al., "Impact of prescribing on new persistent opioid use after cardiothoracic surgery," *The Annals of Thoracic Surgery*, vol. 108, no. 4, pp. 1107–1113, 2019.

[21] K. A. Holst, J. A. Dearani, H. V. Schaff et al., "What drives opioid prescriptions after cardiac surgery: practice or patient?" *The Annals of Thoracic Surgery*, vol. 110, no. 4, pp. 1201–1208, 2020.

[22] H. H. Balkhy, S. Nisivaco, G. Torregrossa et al., "Multispectrum robotic cardiac surgery: early outcomes," *JTCVS Techniques*, vol. 13, pp. 74–82, 2022.