



Research Paper

Risk factors of postoperative intensive care unit admission during the COVID-19 pandemic: A multicentre retrospective cohort study

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ABSTRACT

Background: During the Coronavirus disease 2019 (COVID-19) pandemic, intensive care unit (ICU) capacity was scarce. Since surgical patients also require ICU admission, determining which factors lead to an increased risk of postoperative ICU admission is essential. This study aims to determine which factors led to an increased risk of unplanned postoperative ICU admission during the COVID-19 pandemic.

Methods: This multicentre retrospective cohort study investigated all patients who underwent surgery between 9 March 2020 and 30 June 2020. The primary endpoint was the number of surgical patients requiring postoperative ICU admission. The secondary endpoint was to determine factors leading to an increased risk of unplanned postoperative ICU admission, calculated by multivariate analysis with odds ratios (OR's) and 95% confidence (CI) intervals.

Results: One hundred eighty-five (4.6%) of the 4051 included patients required unplanned postoperative ICU admission. COVID-19 positive patients were at an increased risk of being admitted to the ICU compared to COVID-19 negative (OR 3.14; 95% CI 1.06–9.33; $p = 0.040$) and untested patients (OR 0.48; 95% CI 0.32–0.70; $p = 0.001$). Other predictors were male gender (OR 1.36; 95% CI 1.02–1.82; $p = 0.046$), body mass index (BMI) (OR 1.05; 95% CI 1.02–1.08; $p = 0.001$), surgical urgency and surgical discipline.

Conclusion: A confirmed COVID-19 infection, male gender, elevated BMI, surgical urgency, and surgical discipline were independent factors for an increased risk of unplanned postoperative ICU admission. In the event of similar pandemics, postponing surgery in patients with an increased risk of postoperative ICU admission may be considered.

1. Introduction

Due to the Coronavirus disease 2019 (COVID-19) pandemic caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), hospitals were required to implement several measures to provide additional Intensive Care Unit (ICU) capacity for COVID-19 patients. These measures included performing only (semi)acute surgical procedures, typically those involving oncological procedures, acute gastrointestinal procedures, vascular procedures, and trauma surgery, thereby postponing elective surgical procedures [1–3].

During the pandemic, a proportion of the COVID-19 patients required Intensive Care Unit (ICU) admission, primarily due to respiratory failure [4–7]. In addition, the ICU duration is more prolonged if admitted due to COVID-19 compared to postoperative ICU admission before the pandemic, subsequently putting pressure on overall ICU capacity [8,9]. However, surgical patients could also require ICU admission during the pandemic, despite reduced surgical care. Therefore, prioritization of surgical care during the COVID-19 pandemic was crucial for preserving ICU capacity [3,10].

Since new variants of viruses, including severe acute respiratory

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syndrome coronavirus 2 (SARS-CoV-2), are constantly developing, new mutations could render current COVID-19 vaccines ineffective or cause new pandemics [11,12]. In order to prevent an increasing demand for postoperative ICU capacity in the future and thus pressure on the overall healthcare system, evaluation of surgical patients admitted to the ICU during the pandemic is essential. Specifically, it is crucial to determine which factors determine ICU admission after a surgical procedure. Therefore, this study aims to determine the number and characteristics of the patients who required postoperative ICU admission during the first COVID-19 pandemic wave and which risk factors led to unplanned postoperative ICU admission.

2. Materials and methods

2.1. Patient selection

This retrospective multicentre cohort study included all consecutive surgical patients who underwent surgery between 9 March 2020 and 30 June 2020 in five hospitals in the Netherlands. Patients were included if they were older than 18 years and underwent a surgical procedure in the study period. Patients who were admitted to the hospital due to a COVID-19 infection, patients under 18 years during surgical admission, gynaecological or obstetric procedures, orthopaedic procedures, otolaryngology procedures, cardiothoracic procedures, neurosurgical procedures, urological procedures, and transplantation procedures were excluded. The ethics committee of all participating centres approved this study and decided that informed consent was not required. The current study was performed in accordance with the Strengthening The Reporting Of Cohort Studies in Surgery (STROCSS) guidelines [13]. The study is part of the trial registered in the research registry (www.researchregistry.com), unique identifying number: researchregistry5720).

2.2. Diagnosis of COVID-19

In the early pandemic, preoperative patients were only tested if they were experiencing COVID-19 like symptoms including fever, dyspnoea, cough, chest pain, fatigue, and/or other flu-like symptoms [14]. Reverse transcriptase polymerase chain reaction (PCR) for SARS-CoV-2 was used in all centres according to European guidelines [15]. The genes used for analysis were the RdRP gene, E gene, and the N gene. The E gene assay was used first, followed by confirmatory testing with the RdRp gene assay.

2.3. Endpoints and definitions

The primary endpoint was determining the number of postoperative ICU admissions during the first COVID-19 pandemic wave. The secondary endpoint was determining which factors contribute to unplanned postoperative ICU admission.

Surgical procedures were stratified into four disciplines: general surgery, oncological surgery, trauma surgery, and vascular surgery. General surgical procedures included but were not limited to cholecystectomy, appendectomy, (inguinal) hernia correction, and non-oncological bowel procedures. All procedures were also stratified by setting: acute (A: surgery within 2 h e.g., ruptured aortic aneurysm, bleeding), acute (B: surgery within 24 h e.g., open fracture, anastomotic seam leakage), semi-acute (C: surgery within several weeks e.g., open reduction and internal fixation, operable cancers within 6 weeks), semi-acute (D: surgery within several weeks to months e.g., continuity restoration), elective (E: surgery within months, e.g., removal osteosynthesis material, non-strangulated inguinal hernias), elective (F: surgery with no specific time frame e.g., cosmetic procedures). Prior to surgery, the patient's health status was assessed using the American Society of Anesthesiologists (ASA) classification [16].

Comorbidities included were cardiovascular disease other than the reason for surgery, diabetes mellitus type II, history of malignancy other

than the reason for surgery, history of pulmonary disease other than the reason for surgery and/or history of renal disease other than the reason for surgery.

In our participating hospitals, patients were, according to the (Enhanced Recovery After Surgery) ERAS protocol, not scheduled for postoperative ICU admission [17]. Excepted are the elective open aorta repairs and extended hemihepatectomy (liver resection of more than four segments), which were not classified as unplanned ICU admission. If these patients were admitted to the ICU but stayed for more than one day, they were classified as unplanned ICU admission.

2.4. Statistical analysis

Descriptive statistics were used to display patient and treatment characteristics. Normality was determined using skewness and Kurtosis, in which z-values between -3 and 3 were considered as normally distributed data. Additionally, Shapiro test was used to assess normality [18].

Continuous data are reported as means plus standard deviation (SD) or as medians and interquartile range (IQR), depending on the distribution. Student's T-Test Wilcoxon signed-rank test was used to determine the difference between groups, depending on the distribution. Differences between categorical data were assessed with the Chi-Square test.

Multivariate Imputation by Chained Equations (MICE) using the MICE package in R was performed for imputing missing data. Missing data were compared to non-missing data to determine whether data were missing at random. The imputation was repeated 50 times, followed by applying Rubin's rule to combine parameter estimates and standard errors [19,20]. Imputed data were compared to data for complete cases to determine the validity of the imputation model. The imputed data were used in the analyses.

Multivariate logistic regression analyses were performed to study the risk of unplanned postoperative ICU admission. Odds ratio (OR) and 95% confidence intervals (CI) were used to quantify the risk. Possible confounding factors and effect modifiers were age, sex, body mass index (BMI), surgical discipline, surgical urgency, comorbidity, symptoms associated with COVID-19, and COVID-19 status. Additionally, the multivariate analysis included propensity score (for the testing of COVID-19 with PCR) as an adjusting factor to correct baseline differences between tested and untested patients [21,22]. Two-sided P-values below 0.05 were considered statistically significant. All calculations were performed using RStudio 1.2.5001 (with R version: x64 4.1.1).

3. Results

3.1. Baseline differences between ICU admission and non-ICU admission

Between 9 March 2020 and 30 June 2020, 4051 patients underwent surgical procedures in five Dutch hospitals. Of these patients, 192 (4.7%) were admitted to ICU, of which 185 (96.4%) unplanned. Patients admitted to ICU were significantly older (64.7 vs. 58.1 years, $p < 0.001$), more often male (60.9% vs. 50.7%, $p < 0.007$), and had a higher BMI (26.5 vs. 25.5 kg/m², $p = 0.004$). Of these patients, the most prevalent comorbidities were cardiovascular disease in 121 patients (63.0%, $p < 0.001$), pulmonary disease in 53 patients (27.6%, $p < 0.001$), and diabetes mellitus type II in 39 patients (20.3%, $p < 0.010$). Moreover, the median ICU stay was eight days (range 5–14 days). Most surgical procedures (35.9%) resulting in postoperative ICU admission were performed with type B urgency and (33.9%) type C urgency. Additionally, patients requiring postoperative ICU admission had a significantly higher ASA classification ($p < 0.001$). Vascular procedures (54; 9.5% of included patients) resulted in the highest number of postoperative ICU admissions. Details of the vascular procedures performed are reported in [Supplementary Table 2](#). General surgical procedures (53; 3.1% of included patients) resulted in the lowest number of postoperative ICU

admissions (Table 1). In the ICU, most (57; 29.7%) patients underwent an oncological surgery, and trauma procedures were least represented (28; 14.6%). Of the 496 patients tested for COVID-19 by PCR, 19 (3.8%) tested positive (Supplementary Table 1). In addition, six (3.1%) of the 192 patients tested positive for COVID-19 during the ICU admission (Table 1), all without being tested before the surgical procedure (data not shown).

3.2. Predicting risk of unplanned ICU admission

Multivariate logistic regression analysis was performed to identify the factors determining the risk of unplanned ICU admission after adjusting for possible confounders. Analysis showed that male gender (OR 1.36, 95% CI 1.02–1.82; $p = 0.046$), elevated BMI (OR 1.05, 95% CI 1.02–1.08; $p = 0.014$), more urgent surgical procedure (OR 0.71, 95% CI 0.58–0.86; $p = 0.001$) and surgical discipline for ICU admission increased the risk of unplanned ICU admission. More specifically, the analysis showed that the higher the BMI, the greater the risk of an unplanned postoperative ICU admission. Furthermore, patients testing positive for SARS-CoV-2 during admission were more likely to be admitted to the ICU compared patients testing negative (OR 3.14, 95% CI 1.06–9.33, $p = 0.040$) and untested patients (OR 0.48, 95% CI

0.32–0.70, $p = 0.001$) (Table 2). Patient's age (OR 1.00, 95% CI 0.99–1.02; $p = 0.382$) and number of comorbidities (OR 0.96, 95% CI 0.81–1.13; $p = 0.589$) did not have an increased risk of ICU admission (Table 2).

4. Discussion

This multicentre retrospective cohort study evaluated 4051 surgical patients in five hospitals in the Netherlands during the first wave of the COVID-19 pandemic. One hundred ninety-two patients (4.7%) in this cohort were admitted to the ICU, of which one hundred eighty-five were unplanned. Additionally, 19 (3.8%) patients tested positive for COVID-19. Moreover, a positive COVID-19 test and additional factors including male gender, elevated BMI, higher surgical urgency, and surgical discipline, increased the unplanned postoperative ICU admission risk.

During the first pandemic wave, hospitals around the world, including the Netherlands, took steps to increase ICU capacity for COVID-19 patients by cancelling or postponing (elective) surgical procedures when possible and necessary [1–3,23]. The current study describes the impact of the first COVID-19 pandemic wave on surgical care in five hospitals located in the Netherlands.

The current study showed that ICU admission mainly occurred after vascular surgical procedures, while general surgery resulted in the lowest ICU admissions. In this study, 54 (9.5% of total participants, 28.1% of surgical ICU admissions) vascular patients required postoperative ICU admission. Vascular patients often have multiple comorbidities, including other cardiovascular diseases, COPD, and diabetes [24]. These predispositions are similar to surgical patients with a higher preoperative risk of ICU admission [25,26]. Hence, the surgical discipline may be included to assess which surgical patients are more likely of

Table 1

Baseline characteristics of patients undergoing surgical procedures stratified by ICU admission (N = 4051).

	No ICU admission (N = 3859)	ICU admission (N = 192)	P-value
Age, mean (SD)	58.1 (18.3)	64.7 (15.2)	<0.001 ^a
Sex, male (%)	1955 (50.7%)	117 (60.9%)	<0.007 ^b
BMI Kg/m ² , median (IQR)	25.5 [22.9–28.8]	26.5 [23.4–31.1]	0.004 ^c
ICU stay days, median (IQR)	NA	8 [5–14]	NA
ASA classification			<0.001 ^b
ASA 1, N (%)	970 (25.1%)	12 (6.2%)	
ASA 2, N (%)	1731 (44.9%)	53 (27.6%)	
ASA 3, N (%)	1023 (26.5%)	99 (51.6%)	
ASA 4, N (%)	132 (3.4%)	25 (13.0%)	
ASA 5, N (%)	3 (0.1%)	3 (1.6%)	
Comorbidities			
Cardiovascular disease, N yes (%)	1567 (40.6%)	121 (63.0%)	<0.001 ^b
Diabetes mellitus type II, N Yes (%)	520 (13.5%)	39 (20.3%)	<0.010 ^b
History of malignancy, N yes (%)	596 (15.4%)	33 (17.2%)	0.583 ^b
History of pulmonary disease, N yes (%)	644 (16.7%)	53 (27.6%)	<0.001 ^b
History of renal disease, N yes (%)	365 (9.5%)	31 (16.1%)	0.003 ^b
Surgical urgency			<0.001 ^b
A:	6 (0.2%)	7 (3.6%)	
B:	801 (20.8%)	69 (35.9%)	
C:	1034 (26.8%)	65 (33.9%)	
D:	1397 (36.2%)	43 (22.4%)	
E:	607 (15.7%)	7 (3.6%)	
F:	14 (0.4%)	1 (0.5%)	
Discipline			<0.001
General surgery, N (%)	1663 (43.1%)	53 (27.6%)	
Oncological, N (%)	844 (21.9%)	57 (29.7%)	
Trauma, N (%)	837 (21.7%)	28 (14.6%)	
Vascular, N (%)	515 (13.3%)	54 (28.1%)	
PCR for COVID-19			<0.001
PCR positive, N (%)	13 (0.3%)	6 (3.1%)	
PCR negative, N (%)	405 (10.5%)	71 (37%)	
PCR not performed, N (%)	3434 (89.1%)	115 (59.9%)	

N = number, SD = standard deviation, IQR = interquartile range, BMI = body mass index, ASA = American Society of Anesthesiologists, COVID-19 = coronavirus disease 2019, PCR = Polymerase chain reaction, NA = not applicable.

^a Unpaired *t*-test.

^b Chi-square test.

^c Wilcoxon signed-rank test.

Table 2

Propensity score adjusted multivariate analysis of different factors contributing to the risk of unplanned ICU admission (N = 4051).

Parameter	Estimate (Beta)	OR (95% CI)	Standard error	z-score	P value
Patient age, years	0.005	1.00 (0.99–1.02)	0.006	0.874	0.382
Sex					
Female	NA	1.00 (reference)	NA	NA	NA
Male	0.310	1.36 (1.02–1.82)	0.147	1855	0.046
BMI	0.046	1.05 (1.02–1.08)	0.014	3342	0.001
Number of comorbidities	−0.046	0.96 (0.81–1.13)	0.085	−0.540	0.589
Urgency	−0.343	0.71 (0.58–0.86)	0.100	−3437	0.001
Surgical discipline					
General surgery	NA	1.00 (reference)	NA	NA	NA
Oncological surgery	0.783	2.19 (1.45–3.31)	0.211	3713	<0.001
Trauma surgery	−0.005	1.00 (0.60–1.65)	0.258	−0.018	0.986
Vascular surgery	0.621	1.86 (1.15–3.01)	0.246	2528	0.011
COVID-19					
PCR positive compared to untested	−0.737	0.48 (0.32–0.70)	0.198	−3731	0.001
PCR positive compared to negative	1.143	3.14 (1.06–9.33)	0.556	2057	0.040
PS for being tested for COVID-19	0.032	1.03 (1.02–1.04)	0.004	7359	<0.001

OR = odds ratio, CI = confidence interval, BMI = body mass index, PS = propensity score, COVID-19 = coronavirus disease 2019, PCR = Polymerase chain reaction, NA = not applicable.

ICU admission. As a result, optimal risk stratification and prioritization may contribute to the maintenance of ICU capacity, which may be necessary in the event of an increased need for patients requiring ICU admission. Postponement of elective surgery of vascular patients may be considered due to their increased risk of ICU admission. However, caution is advised since this may lead to increased morbidity in the future [27,28].

This multicentre study showed that male gender, elevated BMI, higher surgical urgency, surgical discipline, and COVID-19 infection increased the risk of ICU admission after a surgical procedure. Several of these predictors and risk factors are similar to patients requiring ICU admission due to COVID-19 [29–31]. Moreover, the multivariate analysis in this study revealed surgical urgency as an independent risk factor for unplanned ICU admission. This is in line with a pre-pandemic study on postoperative ICU admission [32]. Furthermore, the current study showed that patients who tested positive for COVID-19 were more likely to be admitted to the ICU after a surgical procedure than COVID-19 negative and untested patients. This may be explained by previous literature describing, among other things, increased postoperative sepsis and renal, pulmonary, and thromboembolic complication rates in COVID-19 positive patients [33–35]. Additionally, a study showed that patients who underwent surgery during the first wave of the pandemic combined with a positive COVID-19 test during the same admission were at higher risk of in-hospital mortality than patients who underwent surgery without COVID-19 [36].

The current study outlined the surgical practice in the Netherlands by including surgical patients from five different hospitals during the first wave of the COVID-19 pandemic. This study has some limitations. First, our study population was tested if they presented with one or more COVID-19 symptoms. However, symptoms such as fever, cough, and dyspnoea, may be caused by COVID-19, as a presentation of other diseases, or as part of the postoperative course, with a concurrent positive SARS-CoV-2 test [37–42]. Therefore, it may not be feasible to determine the definitive cause of fever in some surgical patients with a positive COVID-19 test. Second, it was difficult to assess the direct risk of ICU admission of COVID-19 since only 19 out of 4051 operated patients during the first COVID-19 pandemic wave tested positive for COVID-19. In addition, the six COVID-19 positive ICU patients were tested during postoperative ICU admission without being tested prior to the surgical procedure. During the first wave in the Netherlands, participants were only tested when presenting with COVID-19-like symptoms, which may have contributed to the relatively low COVID-19 incidence in our study [14]. However, a significant proportion (10–25%) of COVID-19 positive patients are asymptomatic [43,44]. Therefore, surgical procedures may have been performed in patients who were COVID-19 positive with no associated symptoms. As a result, an underestimation of COVID-19 positive patients is possible. Nevertheless, multivariate analysis of the current study showed that several risk factors, including testing positive for COVID-19, contributed to an increased risk of unplanned postoperative ICU admission.

In conclusion, the current study showed the consequences of a new pandemic on ICU capacity and the associated consequences for surgical care. Additionally, this study showed that experiencing COVID-19-like symptoms (regardless of what kind) can lead to postoperative complications, but the risk of postoperative complications is further increased when combined with a positive SARS-CoV-2 test. Furthermore, male gender, elevated BMI, higher surgical urgency, and surgical discipline contributed independently to an increased risk of unplanned postoperative ICU admission in patients who underwent a surgical. These findings result in an essential risk assessment to provide more advanced patient prioritization. Thereby contributing to reducing the risk of postoperative ICU admission and avoiding patient care delays. For similar pandemics, where no vaccine is currently available, consideration should be given to postponing surgical procedures in patients at increased risk of postoperative ICU admission.

Data sharing statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Ethical approval

The ethics committee of all participating centres approved this study and decided that informed consent was not required. METC- protocol number: 20–282/C.

Consent

The ethics committee of all participating centres approved this study and decided that informed consent was not required.

Author contribution

Ellen de Bock: conception and design, analysis and interpretation, data collection, writing the article, critical revision of the article.

Mando D. Filipe: conception and design, analysis and interpretation, data collection, writing the article, critical revision of the article.

Eline S. Herman: analysis and interpretation, data collection, critical revision of the article.

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Milan C. Richir: conception and design, analysis and interpretation, writing the article, critical revision of the article.

Registration of research studies

(www.researchregistry.com, unique identifying number: researchregistry5720).

Guarantor

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Declaration of competing interest

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijso.2023.100620>.

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