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Outcomes and cost-effectiveness of intermediate care units for patients discharged from the intensive care unit: a nationwide retrospective observational study

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Abstract

Background The clinical and economic impacts of intermediate care units (IMCUs) on intensive care unit (ICU)-discharged patients remain unclear due to inconsistent outcomes in previous studies. Under Japan's National Health Insurance Scheme, ICUs are categorized by staffing intensity (high or low). Using a nationwide inpatient database in Japan, we evaluated the clinical outcomes and cost-effectiveness of IMCUs for ICU-discharged patients.

Methods This retrospective observational study used a Japanese administrative database to identify patients admitted to the high-intensity ICU in hospitals with IMCUs between April 2020 and March 2023. Patients were categorized into the IMCU (IMCU group) and general ward (non-IMCU) groups. Propensity scores were estimated using a logistic regression model incorporating 14 variables, including patient demographics, and treatments received during ICU stay. One-to-one propensity score matching balanced baseline characteristics of each group. Clinical outcomes were compared between both groups, including in-hospital mortality, ICU readmission, length of ICU stay, length of hospital stay, and total medical costs. Surgical status and surgical area (e.g., cardiovascular) were considered in subgroup analyses. Data analyses were conducted using the chi-square test for categorical variables and t-test for continuous variables.

Results Overall, 162,243 eligible patients were categorized into the IMCU (n = 21,548) and non-IMCU (n = 140,695) groups. Propensity score matching generated 18,220 pairs. The IMCU group had lower in-hospital mortality and ICU readmission rates than the non-IMCU group. However, total costs were higher in the IMCU group. Subgroup analyses revealed the IMCU group had significantly lower mortality and lower total costs than the non-IMCU group in the cardiovascular [open thoracotomy] surgery subgroup.

Conclusions Discharge to an IMCU is associated with lower in-hospital mortality and ICU readmission rates compared to general ward discharge. High-risk subgroups, such as cardiovascular surgery patients, experienced cost-effective benefits from IMCU care. These findings highlight an association between IMCU admission and improved patient outcomes, suggesting a potential role in optimizing resource use in intensive care. Given the likelihood of selection bias in admission allocation, these findings should be interpretation with caution.

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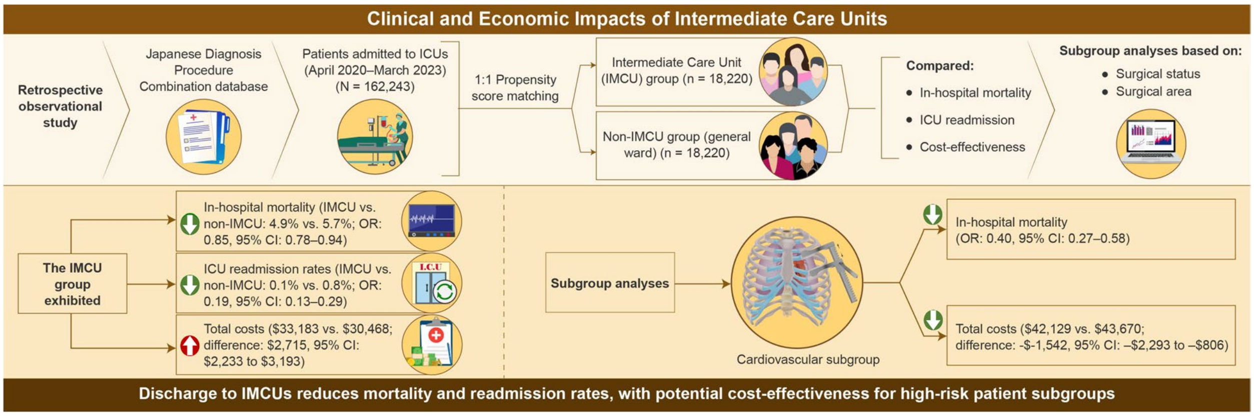
Keywords Intensive care unit, Intermediate care unit, Cost-effectiveness, Diagnosis procedure combination, Administrative database

Graphical abstract



Background

Intensive care units (ICUs) provide the highest level of care in a hospital setting regarding staff and facility resources [1, 2]. Intermediate care units (IMCUs) offer frequent nursing interventions for patients who do not require full ICU care but cannot be adequately managed in the general ward [3, 4]. Guidelines recommend discharge to an IMCU rather than a general ward, especially for patients at high risk of death or ICU readmission, once they no longer require ICU-level observation and treatment [5, 6]. Despite these recommendations, the impact of IMCU transfer on patient outcomes remains inconsistent.

Lekwijit et al. suggested that patients discharged from ICUs to IMCUs had lower in-hospital mortality and shorter stay length than those discharged to general wards [7, 8]. In contrast, Ranzani et al. found no significant prognostic differences between these groups [9]. Moreover, a recent systematic review noted the diverse benefits of IMCUs, including material resources, human resources, continuity of care, and patient benefits, while emphasizing their increasing relevance in hospital care [10–17]. Given this context, further research is needed to clarify the direct impact of IMCUs on patient outcomes and healthcare costs. Specifically, studies should focus on optimizing ICU resource allocation amid high demand and limited medical capacity and evaluating the cost-effectiveness of IMCUs in managing high-risk patients efficiently.

Previous large-scale multicenter studies compared hospitals with IMCUs to those without, demonstrating that the benefits of IMCUs extend even to patients who never directly received IMCU care [8, 18, 19]. However, studies that directly compared patients discharged to IMCUs with those discharged to general wards were conducted at a smaller scale, limiting their generalizability [7, 9]. To address these gaps, our study directly examines in-hospital mortality, ICU readmissions, and total costs between patients discharged to IMCUs and those discharged to general wards.

This study aimed to evaluate whether transfer to an IMCU affects the outcomes and costs for ICU-discharged patients using a large-scale Japanese inpatient database. We hypothesized that transfer to IMCUs, rather than general wards, would have a positive impact on in-hospital outcomes. Specifically, it examined whether such transfers reduced in-hospital mortality, ICU readmissions, lengths of stay in both the ICU and hospital, and total hospital costs.

Methods

Ethics approval and consent to participate

The research utilized a retrospective cohort design based on routinely gathered data, and our research follows the RECORD (Reporting of studies Conducted using Observational Routinely-collected health Data) guidelines [20]. This study was exempt from ethical approval by the Institutional Review Board of Tohoku University (reference no. 2022-1-444). A waiver for written consent was issued due to the anonymized nature of the data.

Study design and data source

This retrospective observational study analyzed data from the Japanese Diagnosis Procedure Combination (DPC) inpatients database [21]. The DPC is a nationwide database comprising administrative claims data and discharge abstracts of over seven million annual hospital admissions collected from nearly 1100 acute care hospitals. The DPC database covers approximately 90% of tertiary-care emergency hospitals in Japan, making it highly representative of acute inpatient care in the country due to its large scale. The database includes the following information: age, sex, body weight and height, smoking history, diagnostic record with the International Classification of Diagnosis, 10th Revision (ICD-10) code, admission type (emergency or elective), hospital type (academic hospital or not), drugs and devices used, surgical procedures, discharge status, and total hospitalization costs. The severity of organ damage was assessed using the Sequential Organ Failure Assessment (SOFA) score for patients admitted to the ICU. The SOFA score is based on physiological parameters (respiration, coagulation, circulation, kidney, liver, and central nervous system), with a total score of 0–24 [22]. In the DPC database, SOFA scores are recorded at three time points: ICU admission day, the day after ICU admission, and ICU discharge day. For this study, the SOFA scores at ICU admission and ICU discharge were included as variables in the propensity score matching (PSM) to adjust for patient severity at the time of ICU admission and discharge. Furthermore, we performed a stratified analysis based on the SOFA score at ICU discharge to better account for disease severity at the time of ICU discharge.

Study population

Patients admitted to the high-intensity ICU in hospitals with IMCUs and enrolled in the DPC database between April 2020 and March 2023 were included. The inclusion criterion was ICU admission during the observation period. The exclusion criteria were as follows: (1) age < 15 years; (2) ICU stay > 14 days; (3) organ transplantation; (4) death in the ICU; and (5) missing or unknown SOFA score data on ICU admission and discharged day. ICU patients who stayed > 14 days were excluded because ICU management fees under the Japanese insurance system were not reimbursable beyond 14 days. Consequently, it was not possible to determine their exact ICU mortality status, ICU length of stay, or discharge destination (IMCU or non-IMCU). There were no restrictions on the length of stay in the pre-ICU. Only the first ICU admission was included in the analysis for patients with multiple ICU admissions during the same hospitalization. After applying these criteria, eligible patients were categorized into two groups: those discharged to the IMCU (IMCU group) and those discharged directly to the general ward (non-IMCU group).

Data collection and variables definition

This study utilized data from the DPC database, including patient demographics, comorbidities, treatment interventions, clinical outcomes, and costs. A full list of collected variables is provided in Additional File 1. Body mass index (BMI) was categorized according to the World Health Organization (WHO) criteria for Asian populations: < 18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9, 30 ≤ kg/m^2, and missing data [23]. In patients with missing BMI values, the mean BMI of the study population was determined. The Charlson Comorbidity Index (CCI) was calculated using a validated coding algorithm and classified into four groups (0, 1, 2, and 3 ≤) [24, 25]. Surgical patients were those undergoing procedures requiring general anesthesia, while non-surgical patients had interventions that did not require general anesthesia or those who did not undergo any procedures. The surgical areas were defined and classified according to the Japanese medical procedure codes into nine groups (intracranial, cardiovascular [open thoracotomy], cardiovascular [percutaneous or transvenous], renal and urinary tract, musculoskeletal, pulmonary and thoracic, upper abdominal, lower abdominal, and others.). The severity of organ damage was assessed using the SOFA score, and patients were classified into six subgroups based on the SOFA score (0–2, 3–5, 6–8, 9–11, 12–14, and 15–24) [26, 27]. ICU (Japanese medical procedure codes A 3011 to A3014) is a specialized facility that provides critical care services. Under Japan's public healthcare insurance scheme, the ICU must have a nurse-to-patient ratio of 1:2 and the equipment necessary to care for critically ill patients. The DPC system in the Japanese National Health Insurance Scheme classifies ICUs into two types according to clinical staffing: (1) equivalent to high-intensity staffed ICUs, and (2) equivalent to low-intensity staffed ICU [28]. The definition of IMCU in this study corresponds to a high-dependency unit (HDU; code A301-2) because the Japanese National Health Insurance System classifies HDUs as general adult intermediate units. IMCUs do not need to be staffed by intensivists, and a nurse-to-patient ratio of 1:4–5 is sufficient. The criteria and requirements for and ICUs and IMCUs, including necessary equipment, treatment capabilities, and patient management standards, are summarized in Additional File 2. The nurse-to-patient ratio in the general wards is 1:7-10.

Outcomes

The primary outcomes of this study were all-cause hospital mortality and total costs. The secondary outcomes included ICU readmission, length of ICU stay, and length of hospital stay. The post hoc analyses assessed the combined length of stay in high-intensity care settings (ICU + IMCU) and readmissions to the IMCU and combined ICU + IMCU to examine their association with patient outcomes. For the IMCU group, IMCU readmission included readmissions to the IMCU following the initial discharge from the IMCU. For the non-IMCU group, readmissions to the IMCU were defined as transfers from the general ward to the IMCU following discharge from the ICU.

Statistical analysis

Patients were divided into two groups according to their discharge destinations: the IMCU (IMCU group) or the general ward (non-IMCU group). Since discharge was not randomized, PSM was used to minimize selection bias and create a well-balanced comparison of outcomes between the two groups. A logistic regression model was employed to estimate propensity scores, incorporating patient characteristics as potential confounders (age, sex, BMI, CCI, use of emergency ambulance, type of admission, general anesthesia, area of surgery, blood transfusion therapy, CRRT, plasma exchange therapy, invasive ventilatory support, and SOFA scores on the day of ICU admission and discharge).

One-to-one nearest-neighbor matching without replacement was performed using the estimated propensity scores for each patient. Covariate balance between the two groups before and after matching was assessed using standardized mean differences (SMD) [29]. After matching, both groups were further categorized into six subgroups based on the SOFA scores on the day of ICU discharge (0–2, 3–5, 6–8, 9–11, 12–14, and 15–24).

To compare categorical variables between the IMCU and non-IMCU groups, chi-squared tests were used, and odds ratios (ORs) and risk ratios (RRs) were calculated with 95% confidence intervals (CI). Continuous variables were analyzed using Student's t-test, and the mean difference with 95% CI was estimated using bootstrap resampling. A total of 10,000 bootstrap samples were generated, and 2.5th and 97.5th percentiles of the mean differences were used to construct the CI.

Continuous and categorical variables are presented as mean (standard deviation) and number (percentage), respectively. Costs are reported in US dollars (USD), with a conversion rate of 123 Japanese yen (JPY) per 1 USD based on the average exchange rate from 2020 to 2023. All analyses were conducted using Python (version 3.7.13).

Subgroup analysis

Several subgroup analyses were performed. Patients were stratified into subgroups based on (1) surgical status (surgery and non-surgery), and (2) surgical area, focusing on the top four surgical categories: intracranial, cardiovascular (open thoracotomy), cardiovascular (percutaneous or transvenous), and upper abdominal. The outcomes of the IMCU and non-IMCU groups were compared within these subgroups.

Sensitivity analysis

Sensitivity analyses were conducted to assess the robustness of our findings and evaluate the impact of missing data and excluded patient groups. The following approaches were applied: (1) multivariable analysis, (2) missing or unknown SOFA scores, and (3) ICU stays > 14 days. We performed multivariable logistic regression and linear regression models to assess the impact of potential confounders on all-cause hospital mortality, ICU readmission, length of ICU stay, length of hospital stay, and total costs. Given that 33.3% of patients had missing or unknown SOFA scores, we compared the baseline characteristics between the included and excluded patient groups using SMD. No imputation was performed, and these patients were excluded from the primary analysis. Patients with ICU stays over 14 days were excluded from the primary analysis due to data limitations in the DPC database. To evaluate potential bias, we analyzed the baseline characteristics and clinical outcomes (in-hospital mortality, ICU readmission, and length of hospital stay) of these patients separately.

Results

A total of 270,727 patients were enrolled during the observation period. The all-cause in-hospital mortality rate for the entire patient population before exclusion was 8.6% (n = 270,727). After applying the exclusion criteria, 162,243 patients were deemed eligible and categorized into IMCU (n = 21,548) and non-IMCU (n = 140,695) groups. After applying the exclusion criteria, this resulted in an overall mortality rate of 5.3% (n = 162,243). Propensity score matching generated 18,220 pairs for comparison (Fig. 1).

Baseline characteristics

Table 1 summarizes the baseline characteristics of patients before and after PSM. Significant differences were observed between the unmatched groups (e.g., emergency admission, area of surgery [cardiovascular, pulmonary and thoracic], blood transfusion therapy, invasive ventilatory support, and SOFA score). After matching, these differences were reduced between the

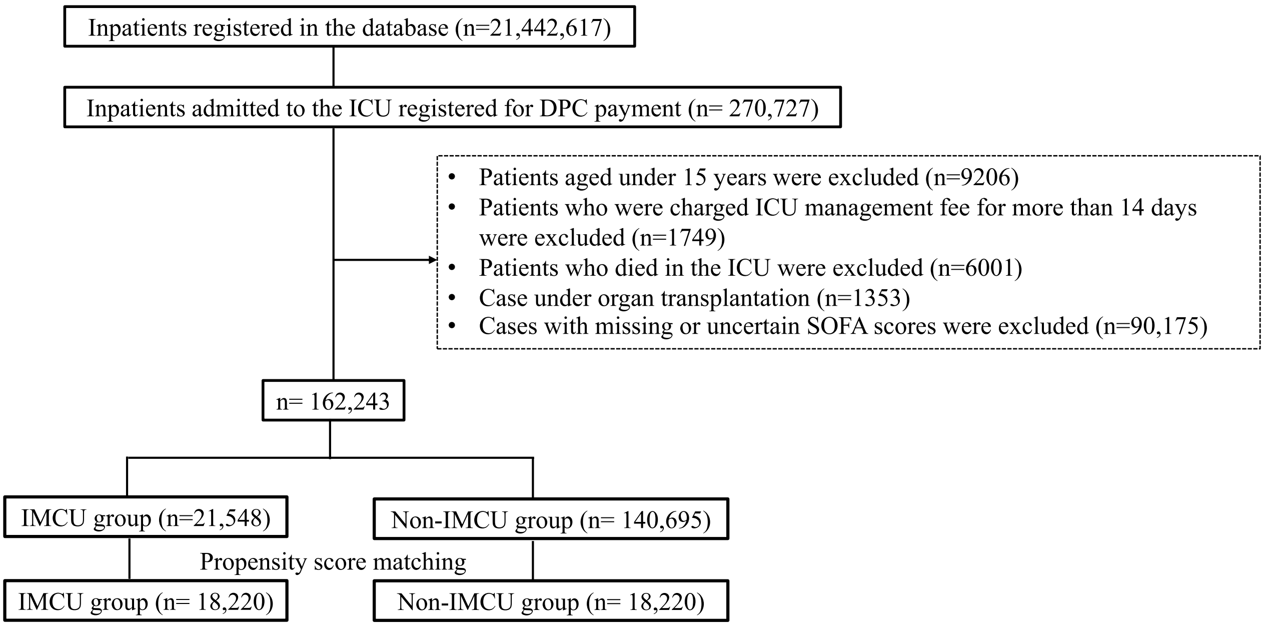


Fig. 1 Flowchart of patient selection. ICU, intensive care unit; DPC, diagnostic procedure combination; SOFA, sequential organ failure assessment

groups, with most SMDs below 0.1, though some variables still showed SMDs up to 0.15. The distribution of propensity scores before and after matching is shown in Additional File 3.

Clinical outcomes

All-cause hospital mortality rate

In the propensity score-matched population (n = 36,440), the overall in-hospital mortality rate was 5.3%. The IMCU group demonstrated statistically lower mortality (4.9% versus 5.7%; OR: 0.85, 95% CI: 0.78–0.94), particularly in SOFA score subgroups of 6–8, 9–11, 12–14, and 15–24 (Fig. 2A, Additional File 4). No significant differences were observed for the SOFA score subgroup of 0–2 and 3–5.

ICU readmission rate

The ICU readmission rates were consistently lower in the IMCU group across all SOFA score categories (0.1% versus 0.8%; OR: 0.19; 95% CI: 0.13–0.29; Fig. 2B, Additional File 4). In contrast, IMCU readmission rates were higher in the IMCU group (483 [2.7%] versus 318 [1.7%]; OR: 1.53; 95% CI: 1.33–1.77). No significant difference was observed in the combined ICU and IMCU readmission rates between the IMCU and non-IMCU groups (510 [2.8%] versus 456 [2.5%]; OR: 1.12; 95% CI: 0.99–1.28).

Length of ICU stay and hospital stay

The IMCU group had shorter ICU stays overall than the non-IMCU group (Fig. 2C, Additional File 4). This trend was consistent across most SOFA score subgroups. In contrast, the length of hospital stay was longer in the IMCU group than in the non-IMCU group (Fig. 2D, Additional File 4). While the length of hospital stay tended to increase as the SOFA score rose in both groups, it was shorter in the SOFA 15–24 subgroup of the IMCU group and in the SOFA 12–14 and 15–24 subgroups of the non-IMCU group. Furthermore, the combined duration of ICU and IMCU stays was significantly longer in the IMCU group than the ICU stay alone in the non-IMCU group (Additional File 4, 5).

Total costs

The total costs were higher in the IMCU group than in the non-IMCU group (mean difference: $2,715, 95% CI: 2,233 to 3,193; Fig. 2E, Additional File 4). However, the cost difference decreased as SOFA scores increased and gradually decreased in the SOFA 6–14 subgroups. In the highest SOFA score subgroup (15–24), total costs were lower in the IMCU group (mean difference: -$13,884, 95% CI: -24,926 to -3,446). A detailed breakdown of cost differences across SOFA subgroups is provided in Additional File 4.

Subgroup analysis

The results of the subgroup analysis based on (1) surgical status (surgical and non-surgical), and (2) area of surgery (intracranial, cardiovascular [open thoracotomy/percutaneous or transvenous], and upper abdominal) are presented in Tables 2 and 3, and Additional Files 6, 7, 8.

Table 1 Baseline characteristics of the IMCU and non-IMCU groups before and after propensity score matching

	Overall	Unmatched group			Matched group		
	(n = 162,243)	IMCU group (n = 21,548)	Non-IMCU group (n = 140,695)	SMD	IMCU group (n = 18,220)	Non-IMCU group (n = 18,220)	SMD
Age	68.5 (14.9)	69.2 (14.0)	69.4 (14.2)	0.05	69.0 (14.0)	69.0 (14.2)	< 0.01
Male	99,341 (61.8%)	13,657 (63.4%)	85,684 (60.9%)	0.05	11,576 (63.5%)	11,839 (65.0%)	0.03
BMI (kg/m^2)				0.03			< 0.01
< 18.5	19,673 (12.1%)	2772 (12.9%)	16,901 (12.0%)		2308 (12.7%)	1748 (9.6%)	
18.5–22.9	69,578 (42.9%)	9354 (43.4%)	60,224 (42.8%)		7890 (43.3%)	8723 (47.9%)	
23.0–24.9	30,076 (18.5%)	3946 (18.3%)	26,130 (18.6%)		3362 (18.5%)	3270 (17.9%)	
25.0–29.9	34,011 (21.0%)	4337 (20.1%)	29,674 (21.1%)		3703 (20.3%)	3786 (20.8%)	
30 ≤	8905 (5.5%)	1139 (5.3%)	7766 (5.5%)		957 (5.3%)	693 (3.8%)	
CCI				0.03			< 0.01
0	61,823 (38.1%)	7816 (36.3%)	54,007 (38.4%)		6756 (37.1%)	6566 (36.0%)	
1	47,646 (29.4%)	6641	41,005 (29.1%)		5541 (30.4%)	5776 (31.7%)	
2	29,094 (17.9%)	3903 (18.1%)	25,191 (17.9%)		3249 (17.8%)	3377 (18.5%)	
3 <	23,680 (14.6%)	3188 (14.8%)	20,492 (14.6%)		2674 (14.7%)	2501 (13.7%)	
Ambulance transportation	48,841 (30.1%)	8127 (37.7%)	40,714 (28.9%)	0.19	6585 (36.1%)	6859 (37.6%)	0.03
Emergency admission	62,176 (38.3%)	9640 (44.7%)	52,536 (37.3%)	0.15	7899 (43.4%)	8174 (44.9%)	0.03
General anesthesia	111,969 (69.0%)	14,038 (65.1%)	97,931 (69.6%)	0.10	12,160 (66.7%)	11,642 (63.9%)	0.06
Area of surgery							
Intracranial	13,543 (8.3%)	1276 (5.9%)	12,267 (8.7%)	0.11	1073 (5.9%)	1037 (5.7%)	< 0.01
Cardiovascular (open thoracotomy)	30,255 (18.6%)	7407 (34.4%)	22,848 (16.2%)	0.43	6391 (35.1%)	5324 (29.2%)	0.13
Cardiovascular (percutaneous or transvenous)	20,795 (12.8%)	1822 (8.5%)	18,973 (13.5%)	0.16	1485 (8.2%)	1759 (9.7%)	0.05
Renal and urinary tract	3655 (2.3%)	160 (0.7%)	3495 (2.5%)	0.14	136 (0.7%)	152 (0.8%)	< 0.01
Musculoskeletal	7433 (4.6%)	452 (2.1%)	6981 (5.0%)	0.16	341 (1.9%)	386 (2.1%)	0.02
Pulmonary and thoracic	9365 (5.8%)	498 (2.3%)	8867 (6.3%)	0.20	443 (2.4%)	525 (2.9%)	0.03
Upper abdominal	17,395 (10.7%)	2232 (10.4%)	15,163 (10.8%)	0.01	2016 (11.1%)	1690 (9.3%)	0.06
Lower abdominal	12,118 (7.5%)	1123 (5.2%)	10,995 (7.8%)	0.11	984 (5.4%)	846 (4.6%)	0.03
Blood transfusion therapy							
RBC transfusion	57,048 (35.2%)	10,664 (49.5%)	46,384 (33.0%)	0.34	9084 (49.9%)	8044 (44.1%)	0.11
Plasma transfusion	35,324 (21.8%)	7883 (36.6%)	27,441 (19.5%)	0.39	6770 (37.2%)	5551 (30.5%)	0.14
Platelet transfusion	22,923 (14.1%)	5020 (23.3%)	17,903 (12.7%)	0.28	4315 (23.7%)	3614 (19.8%)	0.09
Continuous renal replacement therapy	12,028 (7.4%)	1832 (8.5%)	10,196 (7.2%)	0.05	1534 (8.4%)	1339 (7.3%)	0.04
Plasma exchange therapy	648 (0.4%)	85 (0.4%)	563 (0.4%)	< 0.01	74 (0.4%)	28 (0.2%)	0.05
Invasive ventilatory support	51,023 (31.4%)	10,743 (49.9%)	40,280 (28.6%)	0.45	9089 (49.9%)	8140 (44.7%)	0.10
SOFA score at ICU admission day				0.45			0.15
Subgroup 1 (0–2)	81,018 (49.9%)	6660 (30.9%)	74,358 (52.9%)		5699 (31.3%)	6628 (36.4%)	
Subgroup 2 (3–5)	38,856 (23.9%)	5729 (26.6%)	33,127 (23.5%)		4775 (26.2%)	5009 (27.5%)	
Subgroup 3 (6–8)	23,736 (14.6%)	4870 (22.6%)	18,866 (13.4%)		4098 (22.5%)	3776 (20.7%)	
Subgroup 4 (9–11)	13,026 (8.0%)	3044 (14.1%)	9982 (7.1%)		2636 (14.5%)	2137 (11.7%)	
Subgroup 5 (12–14)	4447 (2.7%)	1042 (4.8%)	3405 (2.4%)		861 (4.7%)	577 (3.2%)	
Subgroup 6 (15 -24)	1160 (0.7%)	203 (0.9%)	957 (0.7%)		151 (0.8%)	93 (0.5%)	
SOFA score at ICU discharge day				0.32			0.15
Subgroup 1 (0–2)	103,785 (64.0%)	10,143 (47.1%)	93,642 (66.6%)		8759 (48.1%)	10,016 (55.0%)	

Table 1 (continued)

	Overall	Unmatched group			Matched group		
	(n = 162,243)	IMCU group (n = 21,548)	Non-IMCU group (n = 140,695)	SMD	IMCU group (n = 18,220)	Non-IMCU group (n = 18,220)	SMD
Subgroup 2 (3–5)	40,196 (24.8%)	7309 (33.9%)	32,887 (23.4%)		6104 (33.5%)	5748 (31.5%)	
Subgroup 3 (6–8)	12,271 (7.6%)	3040 (14.1%)	9231 (6.6%)		2530 (13.9%)	1851 (10.2%)	
Subgroup 4 (9–11)	3252 (2.0%)	761 (3.5%)	2491 (1.8%)		607 (3.3%)	418 (2.3%)	
Subgroup 5 (12–14)	1340 (0.8%)	218 (1.0%)	1122 (0.8%)		167 (0.9%)	112 (0.6%)	
Subgroup 6 (15–24)	1399 (0.9%)	77 (0.4%)	1322 (0.9%)		53 (0.3%)	75 (0.4%)	

All values are reported as n (%)

Patient demographics (age, sex, and BMI), clinical severity indicators (CCI, SOFA scores at ICU admission and discharge day), and treatment-related factors (ambulance transportation, area of surgery, invasive ventilation support, continuous renal replacement therapy, and blood transfusion therapy) were included. Continuous variables are expressed as mean ± standard deviation (SD), while categorical variables are reported as frequencies and percentages (%). Standardized mean differences (SMDs) were used to evaluate the balance between the groups before and after propensity score matching. Missing BMI values were imputed using population means

The IMCU group had lower all-cause mortality rates than the non-IMCU group in the non-surgical subgroup and the cardiovascular (open thoracotomy) subgroup, while no significant differences were observed in other surgical subgroups. ICU readmission rates were consistently lower in the IMCU group across all subgroups, including surgical, non-surgical, and cardiovascular (open thoracotomy) patients. ICU length of stay was shorter in the IMCU group in the non-surgical and cardiovascular (open thoracotomy) subgroups, with consistent trends across all SOFA score categories. No significant differences in ICU length of stay were observed in other surgical subgroups. Hospital length of stay was longer in the IMCU group across most subgroups, including surgical, non-surgical, and other surgery categories. In contrast, within the cardiovascular (open thoracotomy) subgroup, there was no significant difference in hospital stay between the IMCU and non-IMCU groups. Total costs differed by subgroup. In the cardiovascular (open thoracotomy) subgroup, costs were lower in the IMCU group, whereas in the surgical, non-surgical, and other surgery subgroups, total costs were higher in the IMCU group than in the non-IMCU group.

Sensitivity analysis

Sensitivity analyses confirmed the robustness of our primary findings. Multivariable regression analyses showed that the IMCU group had lower all-cause hospital mortality and ICU readmission rates compared to the non-IMCU group, along with shorter ICU stays (Additional File 9). The analysis of patients with missing or unknown SOFA scores revealed no substantial differences in baseline characteristics, except for cardiovascular surgery and general anesthesia (Additional File 10). Patients with ICU stays > 14 days had higher rates of emergency admission and invasive ventilatory support, as well as significantly higher in-hospital mortality and ICU readmission rates (Additional File 11). Total costs were lower in the IMCU group than in the non-IMCU group (Additional File 9).

Discussion

Previous studies have reported inconsistent findings regarding the impact of IMCUs on ICU-discharged patients. Some multicenter studies have found an association between IMCU admission and reduced mortality, while others, particularly in resource-limited settings, reported no significant benefit [7–9]. These differences likely reflect variations in study design, resource availability, and patient selection. Our study, based on a large-scale nationwide dataset, suggests an association between IMCU admission and improved outcomes among ICU survivors. This effect was particularly evident in patients with higher SOFA scores and high-risk surgical populations.

The mortality rate in this study exceeded 70% in the non-IMCU group among patients with SOFA scores of 12–14 and 15–24. In Japan, patients requiring mechanical circulatory support (MCS), often subject to withholding and/or withdrawal decisions, tended to be transferred to general wards while continuing MCS and catecholamine administration rather than being downgraded to an IMCU. Patients with ICU discharge SOFA scores of 12–14 and 15–24 were likely considered unsuitable for IMCU transfer due to their poor prognosis. However, the DPC database does not capture variables related to treatment withholding or withdrawal, making it impossible to directly assess this factor in our analysis. Consequently, these patients were more likely to remain in the ICU or be directly transferred to general wards, contributing to the high mortality rate observed in the non-IMCU group.

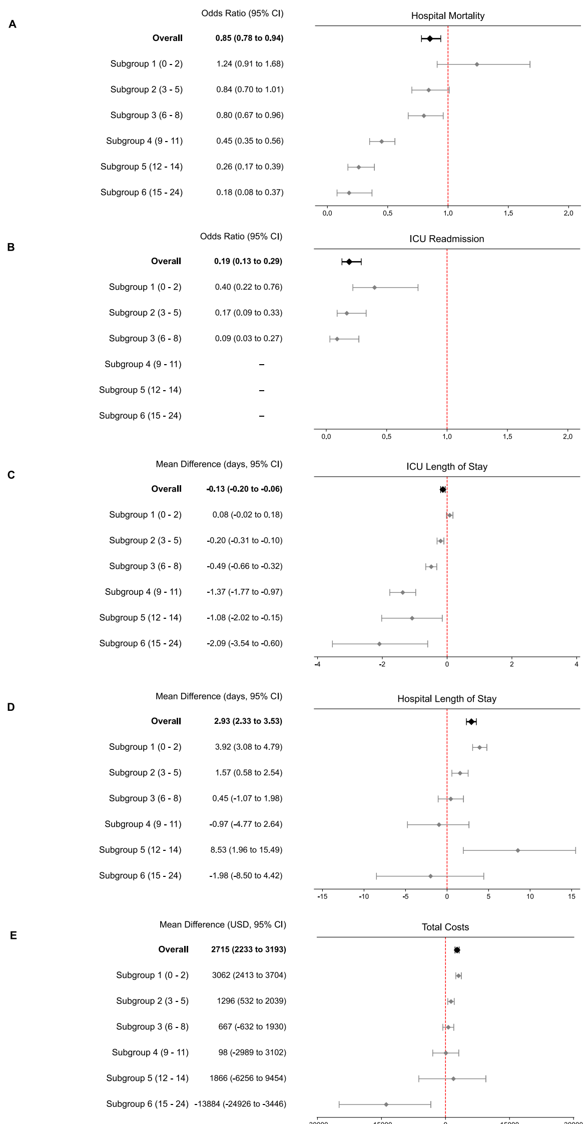


Fig. 2 Outcomes of patients discharged to the IMCU versus non-IMCU after propensity score matching. Outcomes included (**A**) all-cause in-hospital mortality, (**B**) ICU readmission rate, (**C**) length of ICU stay, (**D**) length of hospital stay, and (**E**) total hospital costs. Subgroup analyses were performed according to SOFA score categories at ICU discharge. Results are presented as odds ratios (ORs) with 95% confidence intervals (CIs) for categorical outcomes, and mean differences with 95% CIs for continuous outcomes. Group comparisons were conducted using the chi-square test for categorical variables and the t-test for continuous variables. Costs are reported in US dollars (USD), converted from Japanese yen (JPY) at a rate of 123 JPY/USD. ICU, intensive care unit; SOFA, sequential organ failure assessment

Moreover, patients with SOFA scores of 6–8 and 9–11 in the IMCU group had significantly lower mortality rates than those in the non-IMCU group. Interestingly, in the SOFA 9–11 subgroup, there was no significant difference in total costs between the two groups. These findings suggest that for patients with ICU discharge SOFA scores of 6–8 and 9–11, IMCU admission may be associated with improved survival outcomes while maintaining cost-effectiveness.

Our study also found that patients in the IMCU group remained in high-intensity care settings (ICU and IMCU combined) for an average of 3.5 more days compared to those discharged directly to general wards. This extended stay may have allowed for enhanced monitoring and support, potentially reducing risks associated with premature ICU discharge. As Carlos et al. suggested, IMCU may facilitate a more structured transition for patients recovering from severe illnesses, offering closer monitoring and care before transfer to a general ward [10].

In the subgroup analysis by the surgical category, we found that while mortality was not significantly different between the IMCU and non-IMCU groups for most types of surgery, patients undergoing cardiovascular surgery (open thoracotomy) had lower all-cause mortality rates, reduced ICU readmission rates, shorter ICU and hospital stays, and lower total costs when discharged to an IMCU. Similarly, Carlos et al. reported that after the establishment of an IMCU, cardiovascular surgery patients had shorter ICU and hospital stays. However, they found no significant differences in ICU readmission or in-hospital mortality [10]. These findings suggest that IMCUs may play an important role in optimizing resource use and improving outcomes for high-risk surgical patients. Well-resourced IMCUs can provide enhanced postoperative monitoring, which may help reduce ICU readmission and support cost-effective care. Standardizing IMCU discharge criteria based on patient severity, ICU resources, equipment availability, staffing levels, and regional intensive care demand may improve clinical outcomes and optimize resource allocation.

Our findings revealed that while ICU readmissions were significantly lower in the IMCU group, IMCU readmissions were higher, resulting in no significant difference in the combined ICU + IMCU readmission rates between the two groups. This suggests that IMCU utilization was associated with a shift in readmissions from ICU to IMCU, potentially facilitating a more structured step-down process. IMCU utilization may support a more organized and strategic approach to ICU management by decreasing ICU readmissions and maintaining flexibility in ICU bed availability. Ensuring ICU bed availability is critical for accommodating sudden changes in patient conditions, both within and outside the hospital. By reducing unplanned ICU readmissions, IMCU utilization may allow ICUs to prioritize newly deteriorating patients, leading to more efficient allocation of beds and staff. Additionally, the preference for IMCU readmission over ICU readmission may partially

Table 2 Subgroup analysis categorized by surgical status (surgical and nonsurgical subgroups)

Matched group						
Surgical (n = 23,802)						
Outcomes	**IMCU (n = 12,160)**		**Non-IMCU (n = 11,642)**		**Odds ratio or difference in means**	**95% CI**
Hospital mortality (%)						
Overall	221/12160	(1.8%)	229/11642	(2.0%)	0.92	0.77 to 1.11
Subgroup 1 (0–2)	27/4050	(0.7%)	26/4972	(0.5%)	1.28	0.71 to 2.19
Subgroup 2 (3–5)	64/4897	(1.3%)	54/4427	(1.2%)	1.07	0.74 to 1.54
Subgroup 3 (6–8)	55/2423	(2.3%)	55/1820	(3.0%)	0.75	0.51 to 1.09
Subgroup 4 (9–11)	41/634	(6.5%)	43/348	(12.4%)	0.49	0.31 to 0.77
Subgroup 5 (12–14)	21/116	(18.1%)	25/47	(53.2%)	0.19	0.09 to 0.41
Subgroup 6 (15–24)	13/40	(32.5%)	26/28	(92.9%)	0.04	0.01 to 0.18
ICU readmission (%)						
Overall	16/12160	(0.1%)	82/11642	(0.7%)	0.19	0.11 to 0.32
Subgroup 1 (0–2)	9/4050	(0.2%)	21/4972	(0.4%)	0.53	0.24 to 1.15
Subgroup 2 (3–5)	6/4897	(0.1%)	34/4427	(0.8%)	0.16	0.07 to 0.38
Subgroup 3 (6–8)	1/2423	(0.0%)	24/1820	(1.3%)	0.03	0.00 to 0.23
Subgroup 4 (9–11)	0/634	(0.0%)	3/348	(0.9%)	–	–
Subgroup 5 (12–14)	0/116	(0.0%)	0/47	(0.0%)	–	–
Subgroup 6 (15–24)	0/40	(0.0%)	0/28	(0.0%)	–	–
Length of ICU stay (days)						
Overall	2.9 (2.6)		3.0 (3.0)		−0.05	−0.12 to 0.02
Subgroup 1 (0–2)	2.5 (2.5)		2.4 (2.5)		0.19	0.09 to 0.30
Subgroup 2 (3–5)	3.0 (2.6)		3.2 (3.0)		−0.17	−0.29 to −0.06
Subgroup 3 (6–8)	3.2 (2.6)		3.6 (3.2)		−0.48	−0.67 to −0.30
Subgroup 4 (9–11)	3.4 (2.9)		4.6 (4.2)		−1.22	−1.72 to −0.73
Subgroup 5 (12–14)	4.1 (4.2)		6.7 (5.3)		−2.65	−4.35 to −1.01
Subgroup 6 (15–24)	4.5 (4.8)		9.5 (5.7)		−5.00	−7.47 to −2.43
Length of hospital stay (days)						
Overall	30.1 (26.0)		27.7 (27.0)		2.45	1.78 to 3.13
Subgroup 1 (0–2)	27.8 (27.5)		24.4 (23.6)		3.39	2.34 to 4.47
Subgroup 2 (3–5)	30.2 (24.8)		28.7 (29.5)		1.52	0.37 to 2.62
Subgroup 3 (6–8)	32 (23.1)		32.4 (26.8)		−0.40	−1.93 to 1.14
Subgroup 4 (9–11)	35.4 (27.1)		36.5 (31.7)		−1.09	−5.09 to 2.77
Subgroup 5 (12–14)	43 (20.4)		32.0 (29.5)		11.03	−1.08 to 23.82
Subgroup 6 (15–24)	25.9 (19.4)		30.3 (33.2)		−4.40	−18.50 to 8.21
Total costs (USD)						
Overall	36,450 (21,544)		34,167 (22,562)		2283	1726 to 2849
Subgroup 1 (0–2)	29,840 (20,069)		27,262 (19,322)		2578	1770 to 3403
Subgroup 2 (3–5)	36,823 (19,729)		36,529 (21,707)		295	−545 to 1145
Subgroup 3 (6–8)	42,727 (22,019)		42,746 (22,760)		−18	−1388 to 1354
Subgroup 4 (9–11)	47,447 (23,885)		49,893 (29,491)		−2446	−6071 to 1133
Subgroup 5 (12–14)	55,917 (35,559)		56,658 (35,786)		−742	−13,064 to 11,320
Subgroup 6 (15–24)	48,982 (26,002)		96,038 (50,507)		−47,056	−66,846 to −27,657
Non-surgical (n = 12,638)						
	IMCU (n = 6060)		**Non-IMCU (n = 6578)**		**Odds ratio or difference in means**	**95% CI**
Hospital mortality (%)						
Overall	678/6060	(11.2%)	815/6578	(12.4%)	0.89	0.80 to 0.99

Table 2 (continued)

Non-surgical (n = 12,638)						
	IMCU (n = 6060)		Non-IMCU (n = 6578)		Odds ratio or difference in means	95% CI
Subgroup 1 (0–2)	57/2076	(2.7%)	59/2680	(2.2%)	1.25	0.87 to 1.81
Subgroup 2 (3–5)	166/2188	(7.6%)	203/2278	(8.9%)	0.84	0.68 to 1.04
Subgroup 3 (6–8)	217/1239	(17.5%)	208/1067	(19.5%)	0.88	0.71 to 1.08
Subgroup 4 (9–11)	129/386	(33.4%)	169/337	(50.1%)	0.50	0.37 to 0.67
Subgroup 5 (12–14)	75/132	(56.8%)	102/132	(77.3%)	0.39	0.23 to 0.66
Subgroup 6 (15–24)	34/39	(87.2%)	74/84	(88.1%)	0.92	0.29 to 2.90
ICU readmission (%)						
Overall	11/6060	(0.2%)	56/6578	(0.9%)	0.21	0.11 to 0.40
Subgroup 1 (0–2)	4/2076	(0.2%)	19/2680	(0.7%)	0.27	0.09 to 0.80
Subgroup 2 (3–5)	4/2188	(0.2%)	22/2278	(1.0%)	0.19	0.06 to 0.55
Subgroup 3 (6–8)	3/1239	(0.2%)	9/1067	(0.8%)	0.29	0.08 to 1.06
Subgroup 4 (9–11)	0/386	(0.0%)	5/337	(1.5%)	–	–
Subgroup 5 (12–14)	0/132	(0.0%)	0/132	(0.0%)	–	–
Subgroup 6 (15–24)	0/39	(0.0%)	1/84	(1.2%)	–	–
Length of ICU stay (days)						
Overall	4.4 (3.6)		4.5 (4.0)		− 0.16	− 0.29 to − 0.02
Subgroup 1 (0–2)	3.8 (3.3)		3.9 (3.4)		− 0.09	− 0.28 to 0.10
Subgroup 2 (3–5)	4.4 (3.6)		4.6 (3.9)		− 0.14	− 0.37 to 0.08
Subgroup 3 (6–8)	4.8 (3.7)		5.2 (4.3)		− 0.36	− 0.69 to − 0.03
Subgroup 4 (9–11)	4.8 (3.9)		6.0 (4.9)		− 1.18	− 1.82 to − 0.53
Subgroup 5 (12–14)	6.3 (4.4)		6.2 (5.3)		0.08	− 1.10 to 1.25
Subgroup 6 (15–24)	6.3 (4.9)		6.8 (5.2)		− 0.49	− 2.32 to 1.38
Length of hospital stay (days)						
Overall	32.8 (33.7)		28.8 (31.6)		3.98	2.84 to 5.12
Subgroup 1 (0–2)	26.6 (26.2)		21.7 (22.4)		4.86	3.45 to 6.29
Subgroup 2 (3–5)	34.1 (32.6)		32.1 (33.3)		2.02	0.08 to 3.93
Subgroup 3 (6–8)	39.4 (43.1)		36.9 (36.6)		2.54	− 0.63 to 5.76
Subgroup 4 (9–11)	37.5 (38.2)		37.8 (49.6)		− 0.37	− 7.10 to 5.91
Subgroup 5 (12–14)	34.7 (29.0)		29.4 (31.4)		5.34	− 1.89 to 12.58
Subgroup 6 (15–24)	20.7 (16.7)		23.6 (24.5)		− 2.92	− 10.10 to 4.50
Total costs (USD)						
Overall	26,626 (21,854)		23,921 (27,069)		2706	1850 to 3546
Subgroup 1 (0–2)	22,609 (17,841)		18,884 (16,763)		3726	2724 to 4728
Subgroup 2 (3–5)	27,022 (22,214)		24,672 (27,428)		2350	896 to 3802
Subgroup 3 (6–8)	30,299 (24,230)		29,514 (34,568)		785	− 1771 to 3178
Subgroup 4 (9–11)	31,621 (26,786)		32,547 (36,715)		− 926	− 5892 to 3707
Subgroup 5 (12–14)	33,915 (22,817)		37,241 (49,627)		− 3326	− 13,151 to 5437
Subgroup 6 (15–24)	27,457 (20,200)		37,640 (40,639)		− 10,183	− 21,174 to 235

Outcomes included all-cause in-hospital mortality, ICU readmission rates, length of ICU stay, length of hospital stay, and total hospital costs. Subgroup analyses were performed according to SOFA score categories at ICU discharge. Mortality and readmission rates are expressed as frequencies and percentages (%). The length of ICU stay, length of hospital stay, and total costs were reported as mean ± standard deviation (SD). The results were presented as odds ratios (OR) with 95% confidence intervals (CIs) for categorical outcomes and mean differences (95% CI) for continuous outcomes. Group comparisons were conducted using the chi-square test for categorical variables and the t-test for continuous variables

explain the observed cost differences. Since IMCU care costs are significantly lower than ICU care (daily management cost in Japan: ICU versus IMCU; $1155 versus $557), shifting readmissions from ICU to IMCU may contribute to overall cost savings while maintaining high-quality patient care. These findings highlight the potential role of IMCUs in optimizing resource utilization in intensive care settings.

Table 3 Clinical outcomes and costs for patients undergoing cardiovascular [open thoracotomy] surgery

Matched group						
Cardiovascular (Open thoracotomy; n = 11,715)						
Outcome	**IMCU (n = 6391)**		**Non-IMCU (n = 5324)**		**Odds ratio or difference in means**	**95% CI**
Hospital mortality (%)						
Overall	41/6391	(0.6%)	85/5324	(1.6%)	0.40	0.27 to 0.58
Subgroup 1 (0–2)	1/1180	(0.1%)	3/1228	(0.2%)	0.35	0.04 to 3.33
Subgroup 2 (3–5)	7/2852	(0.2%)	12/2493	(0.5%)	0.51	0.20 to 1.29
Subgroup 3 (6–8)	7/1750	(0.4%)	23/1303	(1.8%)	0.22	0.10 to 0.52
Subgroup 4 (9–11)	14/494	(2.8%)	14/249	(5.6%)	0.49	0.23 to 1.04
Subgroup 5 (12–14)	5/86	(5.8%)	11/27	(40.7%)	0.09	0.0 to 0.29
Subgroup 6 (15–24)	7/29	(24.1%)	22/24	(91.7%)	0.03	0.01 to 0.16
ICU readmission (%)						
Overall	2/6391	(0.0%)	40/5324	(0.8%)	0.04	0.01 to 0.17
Subgroup 1 (0–2)	1/1180	(0.1%)	4/1228	(0.3%)	0.26	0.03 to 2.33
Subgroup 2 (3–5)	1/2852	(0.0%)	21/2493	(0.8%)	0.04	0.01 to 0.32
Subgroup 3 (6–8)	0/1750	(0.0%)	14/1303	(1.1%)	–	–
Subgroup 4 (9–11)	0/494	(0.0%)	1/249	(0.4%)	–	–
Subgroup 5 (12–14)	0/86	(0.0%)	0/27	(0.0%)	–	–
Subgroup 6 (15–24)	0/29	(0.0%)	0/24	(0.0%)	–	–
Length of ICU stay (days)						
Overall	3.2 (2.5)		4.0 (3.1)		− 0.76	− 0.87 to − 0.66
Subgroup 1 (0–2)	3.5 (2.6)		4.3 (3.0)		− 0.80	− 1.02 to − 0.57
Subgroup 2 (3–5)	3.2 (2.4)		3.8 (2.9)		− 0.61	− 0.75 to − 0.46
Subgroup 3 (6–8)	3.1 (2.3)		3.8 (3.0)		− 0.70	− 0.89 to − 0.51
Subgroup 4 (9–11)	3.1 (2.5)		4.5 (3.9)		− 1.41	− 1.95 to − 0.88
Subgroup 5 (12–14)	3.6 (4.0)		6.0 (5.0)		− 2.46	− 4.53 to − 1.45
Subgroup 6 (15–24)	3.8 (4.1)		9.8 (5.5)		− 6.03	− 8.49 to − 3.34
Length of hospital stay (days)						
Overall	27.4 (18.4)		27.7 (21.2)		− 0.28	− 1.00 to 0.44
Subgroup 1 (0–2)	24.8 (16.1)		25.7 (17.8)		− 0.94	− 2.32 to 0.43
Subgroup 2 (3–5)	26.5 (16.6)		26.4 (20.4)		0.14	− 0.86 to 1.13
Subgroup 3 (6–8)	28.7 (18.1)		30.4 (22.7)		− 1.72	− 3.26 to − 0.26
Subgroup 4 (9–11)	32.1 (22.6)		35.4 (30.4)		− 3.23	− 7.80 to 0.74
Subgroup 5 (12–14)	41.5 (49.8)		33.1 (30.0)		8.45	− 7.34 to 24.07
Subgroup 6 (15–24)	22.8 (15.6)		31.8 (35.1)		− 9.01	− 24.65 to 5.07
Total costs (USD)						
Overall	42,129 (18,326)		43,670 (22,044)		− 1542	− 2293 to − 806
Subgroup 1 (0–2)	38,463 (16,851)		40,571 (21,256)		− 2108	− 3668 to − 585
Subgroup 2 (3–5)	40,534 (17,117)		41,908 (20,006)		− 1374	− 2382 to − 396
Subgroup 3 (6–8)	44,347 (16,628)		46,492 (21,239)		− 2145	− 3506 to − 751
Subgroup 4 (9–11)	48,687 (23,507)		53,974 (28,759)		− 5287	− 9564 to − 1278
Subgroup 5 (12–14)	61,018 (37,544)		66,211 (38,828)		− 5194	− 22,273 to 10,848
Subgroup 6 (15–24)	46,488 (23,754)		99,820 (49,943)		− 53,332	− 74,801 to − 32,539

Outcomes included all-cause in-hospital mortality, ICU readmission rates, length of ICU stay, length of hospital stay, and total hospital costs. Subgroup analyses were performed according to SOFA score categories at ICU discharge. Mortality and readmission rates are expressed as frequencies and percentages (%). The length of ICU stay, length of hospital stay, and total costs were reported as mean ± standard deviation (SD). The results were presented as odds ratios (OR) with 95% confidence intervals (CIs) for categorical outcomes and mean differences (95% CI) for continuous outcomes. Group comparisons were conducted using the chi-square test for categorical variables and the t-test for continuous variables

Systematic reviews have noted that the cost-effectiveness of IMCUs remains inconclusive, highlighting the need for further research in this area [11, 30]. López-Jardón et al. emphasized the variability in cost-effectiveness evaluation methods and recommended total hospital costs over the entire admission period as a standardized metric [11, 15, 17]. These observations highlight the challenges of achieving consistent economic evaluations of IMCUs across different studies and healthcare systems. In our study, total hospital costs were not reduced in the overall patient population. However, certain high-risk subgroups, such as patients with SOFA scores of 9–11 or higher and those recovering from cardiovascular surgery, were associated with lower total costs in the IMCU group compared to the non-IMCU group. One possible explanation is that patients with higher SOFA scores at ICU discharge are at increased risk of complications such as sepsis, acute kidney injury, and post-intensive care unit (PICU) syndrome, which often result in prolonged hospitalization and additional therapeutic interventions [31–34]. Enhanced monitoring and timely interventions in the IMCU may help mitigate these risks, potentially reducing the need for extended treatment or ICU readmission. These findings suggest that IMCUs may play a crucial role in providing cost-effective care for selected high-risk patients by facilitating safer and more efficient transitions from the ICU, reducing unnecessary resource utilization, and optimizing care pathways. However, given the limitations of our findings and the variability in prior research, further investigations using standardized cost-evaluation methods are necessary. Future studies should identify the most cost-effective strategies for IMCU utilization and explore how variations in healthcare systems, resource allocation, and patient demographics influence their economic and clinical impact. Establishing evidence on the cost-effectiveness of IMCUs will enable more informed decision-making and support the development of targeted policies to optimize intensive care resources across diverse healthcare settings.

Our study has limitations. First, we used PSM to minimize selection bias and improve comparability between the IMCU and non-IMCU groups. However, as a retrospective observational study, it remains subject to certain limitations. Unlike randomized controlled trials, PSM cannot eliminate all biases due to the non-randomized treatment allocation. Moreover, PSM can only adjust for observed variables, meaning that unmeasured confounding factors may still exist, potentially leading to residual confounding. Second, the multivariable analysis suggested lower total costs in the IMCU group, differing from the higher costs observed in the primary analysis. This discrepancy underscores the influence of methodological differences in cost evaluations, highlighting the need for careful interpretation of cost-related findings. Despite these discrepancies, the primary conclusions remained consistent. Third, many patients with missing or unknown SOFA scores were excluded, accounting for 33.3% of the total population (90, 175/270, 727). Although a sensitivity analysis showed that the baseline characteristics of the excluded group were comparable to those included in the analysis based on SMDs, the potential impact of this exclusion cannot be entirely disregarded. Fourth, patients with an ICU stay exceeding 14 days were excluded. While a sensitivity analysis was conducted, these patients exhibited larger SMDs and higher mortality rates compared to those included in the study. Their exclusion may affect overall findings; however, their high mortality and resource utilization suggest that many underwent treatment withdrawal or died in the ICU, reinforcing their categorization as a unique subgroup. Fifth, care withdrawal was not accounted for in this analysis. Patients for whom withdrawal of care was decided were more likely to be transferred from the ICU to general wards, potentially contributing to the higher mortality rate observed in the non-IMCU group. Finally, multiple comparisons may have increased the risk of type I errors. Although rigorous statistical analyses were conducted, adjustments for multiplicity were not applied due to the exploratory nature of the subgroup analyses. Thus, these findings should be interpreted with caution.

Conclusions

In this observational study of acute care hospitals across Japan, transfer to an IMCU was associated with lower in-hospital mortality and ICU readmission rates compared to transfer to a non-IMCU. However, as this study is observational, residual confounding and unmeasured factors cannot be excluded. While IMCUs are not universally cost-saving, they improve clinical outcomes, and careful patient selection may optimize both outcomes and economic benefits. Given these limitations, further prospective studies or controlled trials should be conducted to establish causality and refine patient selection criteria.

Abbreviations

ICU	Intensive care unit
IMCU	Intermediate care unit
HDU	High dependency unit
SOFA	Sequential organ failure assessment
DPC	Diagnosis procedure combination
ICD-10	International classification of diseases, 10th revision
PSM	Propensity score matching
RECORD	Reporting of studies conducted using observational routinely-collected health data
BMI	Body mass index
CCI	Charlson comorbidity index
CRRT	Continuous renal replacement therapy
OR	Odds ratio
RR	Risk ratio

CI	Confidence interval
SMD	Standardized mean difference
USD	United States dollar
JPY	Japanese yen

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13054-025-05393-9.

Supplementary file1 (XLSX 9 KB)
Supplementary file2 (XLSX 11 KB)
Supplementary file3 (PNG 169 KB)
Supplementary file4 (XLSX 14 KB)
Supplementary file5 (XLSX 34 KB)
Supplementary file6 (XLSX 10 KB)
Supplementary file7 (XLSX 22 KB)
Supplementary file8 (XLSX 11 KB)
Supplementary file9 (XLSX 12 KB)
Supplementary file10 (XLSX 13 KB)
Supplementary file11 (XLSX 13 KB)
Supplementary file12 (DOCX 17 KB)

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Author contributions
SI, KF and TS contributed to the study concept and design. KT, KF, and KF acquired the data. SI, KT, YK, TI, SY, YI, YW, and YI analyzed and interpreted the data. SI drafted the manuscript. TS, YK, TI, YI, YW, SY, ET, YI, KF, and MY critically revised the manuscript for important intellectual content. SI, TI, and YK performed the statistical analysis. SI, KF, and KF obtained funding. TS, YK, TI, YI, SY, YW, ET, YI, KF and MY provided administrative, technical, and logistic support. MY supervised the study. All authors read and approved the final manuscript.

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Availability of data and materials
The dataset analyzed in the current study is not publicly available because of contracts with the hospitals that provided the data to the database.

Declarations

Ethics approval and consent to participate
This study was exempt from ethical approval by the Institutional Review Board of the University of Tohoku (reference no. 2022-1-444), which waived the requirement for informed patient consent because of the anonymous nature of the data.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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