

Original Article

# Decreased use of red blood cell transfusion and associated factors for pancreatic cancer surgery

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**Backgrounds/Aims:** This study investigated perioperative patterns of red blood cell (RBC) transfusion and related determinants in pancreatic cancer surgery using a nationwide Korean database.

**Methods:** We assessed data from the National Health Insurance Service (NHIS) from 2012 to 2020, including newly diagnosed pancreatic cancer patients aged  $\geq 20$  years who underwent pancreatic surgery within one-year of their diagnosis. Perioperative RBC transfusion was defined as receiving  $\geq 1$  unit of allogenic RBCs from one week before surgery through hospital discharge.

**Results:** Of the 10,473 patients, 18% underwent perioperative RBC transfusions. The transfusion rate declined from 20.1% in 2012 to 12.7% in 2015, followed by an increase to 19.9% in 2020. In a multivariate analysis, each 10-year increase in age (odds ratio [OR], 1.30; 95% confidence interval [CI], 1.24–1.37), female sex (OR, 1.16; 95% CI, 1.05–1.29), and being in the lowest-income quartile compared to the highest (OR, 1.29; 95% CI, 1.11–1.49) were associated with an increased likelihood of requiring RBC transfusions. A higher Charlson comorbidity index was independently connected to a greater risk as well. Compared with pancreaticoduodenectomy, total pancreatectomy had higher odds (OR, 1.91; 95% CI, 1.56–2.35), whereas distal pancreatectomy had lower odds. Furthermore, general hospitals, compared with tertiary hospitals, were associated with higher transfusion probability (OR, 1.38; 95% CI, 1.22–1.56).

**Conclusions:** Given rising RBC transfusion rates among low-income patients and limited NHIS coverage for new transfusion-sparing methods, Korea should prioritize broader adoption of multidisciplinary blood management over continued reliance on transfusion.

**Key Words:** Erythrocyte transfusion; Pancreatic neoplasms; Surgical procedures, operative

## INTRODUCTION

Pancreatic cancer is the seventh leading cause of cancer-related deaths worldwide [1] and the fifth leading cause of

cancer-related deaths in Korea [2] in 2020. Surgical resection remains the only potentially curative option for pancreatic cancer; however, the proportion of patients who are actually cured remains low [3]. Perioperative anemia frequently develops in patients undergoing pancreatic surgery, often leading to the need for transfusion. Among the various transfusion modalities, previous research has mainly focused on perioperative red blood cell (RBC) transfusion [4-6]. The reported perioperative RBC transfusion rate among patients undergoing pancreatic surgery ranges from 20% to 66%, with variability influenced by patient characteristics, type of surgery, institutional policies, and surgeons [5-7]. Although transfusion in anemic patients can aid in improving end-organ oxygenation, perioperative transfusion has been linked to adverse short-term and long-term outcomes in pancreatic cancer patients [7-10]. Short-term negative outcomes include prolonged hospitalization, increased

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risk of postoperative infection, cardiac complications, respiratory failure, and in-hospital mortality, while long-term effects consist of increased cancer recurrence and decreased overall survival [7-10].

Given that blood is a finite resource and considering the risk of viral transmission or clinical complications from transfusions, a restrictive transfusion strategy is recommended to minimize patients' exposure to blood products. This strategy has been shown to lower transfusion-related adverse clinical outcomes compared to liberal transfusion [11]. Moreover, multidisciplinary patient blood management (PBM) programs have been implemented across various clinical environments to decrease allogenic blood transfusion. Although reducing transfusion rates is important, pancreatic cancer surgery presents with high transfusion and morbidity rates, and both restrictive transfusion and PBM are relatively novel initiatives in this context [12]. Evidence indicates that following the initiation of measures to limit transfusions, the frequency of blood transfusion in pancreatic surgery has declined [6,7,13]. Nevertheless, most research examining transfusion trends has focused on Western populations [6,7,13], and there is a paucity of data from Asian settings.

Therefore, this study evaluated RBC transfusion in patients with pancreatic cancer undergoing pancreatic surgery using a nationwide database, and analyzed population-level transfusion trends from 2012 to 2020. In addition, we examined factors associated with RBC transfusion.

## MATERIALS AND METHODS

### Data source and study population

We conducted a population-based retrospective study to determine the rate and temporal trends of RBC transfusion among individuals diagnosed with pancreatic cancer who underwent pancreatic surgery. Data were obtained from a customized National Health Insurance Service - National Health Information Database (NHIS-NHID) in Korea. The NHIS is a compulsory health insurance program that covers the entire resident population of Korea, and contains data on demographics, healthcare utilization, and prescribed medications for individuals under a fee-for-service reimbursement structure.

First, we identified all patients aged  $\geq 20$  years with newly diagnosed pancreatic cancer from 2012 to 2020, as determined by healthcare utilization records containing pancreatic cancer disease codes (C25) from the International Classification of Diseases 10th (ICD-10), combined with the catastrophic illness code linked to cost exemption for high economic burden diseases, including cancer, in the NHIS system in Korea [14]. The period from 2002 to 2011 was designated as a washout window, and individuals who accessed health care services for any cancer during this time were excluded. From this cohort, only patients who underwent pancreatic surgery within one-year of a pancreatic cancer diagnosis were included. Eligibility

for surgical procedures was confirmed by identifying relevant administrative codes for reimbursement within the NHIS. For patients who had multiple pancreatic surgeries, the surgery nearest to the cancer diagnosis was assigned as the surgery date. We further excluded individuals whose death occurred before or on the date of diagnosis. This study was approved by the Institutional Review Board of the Hanyang University College of Medicine (approval no. HYUIRB-202207-001 and NYUIRB-202211-009). Following IRB approval, permission to access the NHIS-NHID was obtained, and all data were anonymized to protect individual identities.

### Definition of RBC transfusion

RBC transfusion was defined as a prescription for  $\geq 1$  unit of allogenic RBC transfusion, recorded by physicians, administered from one week before pancreatic surgery to within 30 days postoperatively in the NHIS-NHID. Transfusion status was categorized as a binary variable, indicating whether a patient was transfused or not.

### Covariates

Age per 10-year increment, sex, residential area, income, Charlson comorbidity index (CCI) score, days from cancer diagnosis to surgery, type of pancreatic surgery, type of medical institution where the surgery was performed, and year of surgery were treated as covariates. The residential area was classified as either a metropolitan city or a non-metropolitan area. The income level variable was re-categorized into four groups based on the 20 percentile groups of the NHIS premium, which reflects individual income: medical aid (rank 0), ranks 1 to 5, ranks 6 to 10, ranks 11 to 15, or ranks 16 to 20. The CCI score was determined by using ICD-10 codes for primary and secondary diagnoses according to the system proposed by Quan et al. [15,16], recorded within the 24 months preceding pancreatic surgery, with original weights assigned in the range of 1 to 6 [17], and subsequently grouped as  $\leq 3$ , 4-5, and  $\geq 6$ . Following a diagnosis of pancreatic cancer, 80% of patients proceeded to surgery within 30 days. The interval from diagnosis to surgery was divided into three groups— $< 14$  days, 14-30 days, and  $> 30$  days—based on its observed distribution. Pancreatic surgery types were categorized into pancreaticoduodenectomy (including Whipple procedure and pylorus preserving pancreaticoduodenectomy), distal pancreatectomy (including pancreatectomy and spleen preserving distal pancreatectomy), total pancreatectomy, and other pancreatectomies. The type of medical institution where the pancreatic surgery was performed was categorized as either a tertiary hospital or a general hospital.

### Statistical analysis

The baseline characteristics, stratified by RBC transfusion status, were described and chi-square tests were conducted. The temporal trends in the proportion of RBC transfusion

**Table 1.** Sociodemographic and clinical characteristics for pancreatic cancer surgery, stratified according to perioperative red blood cell (RBC) transfusion status

	All patients (n = 10,473)	Patients with perioperative RBC transfusion (n = 1,873)	Patients without perioperative RBC transfusion (n = 8,600)	p-value
Age at surgery (yr)				
Mean (SD)	63.7 (11.2)	66.5 (11.1)	63.1 (11.2)	< 0.001
Median (IQR)	65 (15.0)	68 (16)	64 (15)	
Sex				
Male	5,765 (55.0)	969 (51.7)	4,796 (55.8)	0.0015
Female	4,708 (45.0)	904 (48.3)	3,804 (44.2)	
Residential area				
Metropolitan	4,742(45.3)	834 (44.5)	3,908 (45.4)	0.4713
Non-metropolitan	5,731(54.7)	1,039 (55.5)	4,692 (54.6)	
Income				
Medical aid	410 (3.9)	90 (4.8)	320 (3.7)	< 0.0054
1st quartile	1,769 (16.9)	349 (18.6)	1,420 (16.5)	
2nd quartile	1,758 (16.8)	331 (17.7)	1,427 (16.6)	
3rd quartile	2,428 (23.2)	419 (22.4)	2,009 (23.4)	
4th quartile	4,108 (39.2)	684 (36.5)	3,424 (39.8)	
Charlson comorbidity index				
Myocardial infarction	141 (1.3)	29 (1.5)	112 (1.3)	< 0.001
Congestive heart failure	376 (3.6)	84 (4.5)	292 (3.4)	
Peripheral vascular disease	823 (7.9)	172 (9.2)	651 (7.6)	
Cerebrovascular disease	866 (8.3)	173 (9.2)	693 (8.1)	
Dementia	251 (2.4)	65 (3.5)	186 (2.2)	
Chronic pulmonary disease	2,283 (21.8)	440 (23.5)	1,843 (21.4)	
Rheumatic disease	207 (2.0)	39 (2.1)	168 (2)	
Peptic ulcer disease	2,661 (25.4)	459 (24.5)	2,202 (25.6)	
Mild liver disease	2,962 (28.3)	515 (27.5)	2,447 (28.5)	
Diabetes without chronic complication	4,686 (44.7)	879 (46.9)	3,807 (44.3)	
Diabetes with chronic complication	1,406 (13.4)	296 (15.8)	1,110 (12.9)	
Hemiplegia or paraplegia	37 (0.4)	7 (0.4)	30 (0.3)	
Renal disease	185 (1.8)	33 (1.8)	152 (1.8)	
Malignant tumor	10,473 (100.0)	1,873 (100.0)	8,600 (100.0)	
Moderate or severe liver disease	47 (0.4)	7 (0.4)	40 (0.5)	
Metastatic solid tumor	1,207 (11.5)	265 (14.1)	942 (11.0)	
AIDS/HIV	2 (0)	1 (0.1)	1 (0)	
Charlson comorbidity index score				
Mean (SD)	4.5 (2.4)	4.7 (2.6)	4.4 (2.3)	< 0.001
Median (IQR)	4 (2.0)	4 (3.0)	4 (2.0)	
≤ 3	4,711 (45.0)	765 (40.8)	3,946 (45.9)	< 0.001
4–5	3,321 (31.7)	606 (32.4)	2,715 (31.6)	
≥ 6	2,441 (23.3)	502 (26.8)	1,939 (22.5)	
Days from cancer diagnosis to surgery				
Mean (SD)	27.4 (54.1)	26.5 (54.6)	27.6 (54.0)	0.4417
Median (IQR)	9 (23.0)	8 (22.0)	9 (24.0)	
< 14	6,485 (61.9)	1,205 (64.3)	5,280 (61.4)	0.0595
14–30	2,047 (19.5)	321 (17.1)	1,705 (19.8)	
> 30	1,941 (18.5)	326 (17.4)	1,615 (18.8)	

**Table 1.** Continued

	All patients	Patients with perioperative RBC transfusion	Patients without perioperative RBC transfusion	<i>p</i> -value
<b>Pancreatic surgery methods</b>				
Pancreaticoduodenectomy	6,432 (61.4)	1,235 (65.9)	5,197 (60.4)	< 0.001
Distal pancreatectomy	3,079 (29.4)	408 (21.8)	2,671 (31.1)	
Total pancreatectomy	473 (4.5)	149 (8.0)	324 (3.8)	
Other pancreatectomy	489 (4.7)	81 (4.3)	408 (4.7)	
<b>Medical institution type</b>				
Tertiary hospital	8,540 (81.5)	1,421 (75.9)	7,119 (82.8)	< 0.001
General hospital	1,933 (18.5)	452 (24.1)	1,481 (17.2)	
<b>Year of surgery</b>				
2012	870 (8.3)	176 (9.4)	694 (8.1)	< 0.001
2013	996 (9.5)	188 (10)	808 (9.4)	
2014	976 (9.3)	182 (9.7)	794 (9.2)	
2015	1,098 (10.5)	136 (7.3)	962 (11.2)	
2016	1,167 (11.1)	209 (11.2)	958 (11.1)	
2017	1,284 (12.3)	240 (12.8)	1,044 (12.1)	
2018	1,303 (12.4)	214 (11.4)	1,089 (12.7)	
2019	1,444 (13.8)	258 (13.8)	1,186 (13.8)	
2020	1,335 (12.7)	270 (14.4)	1,065 (12.4)	

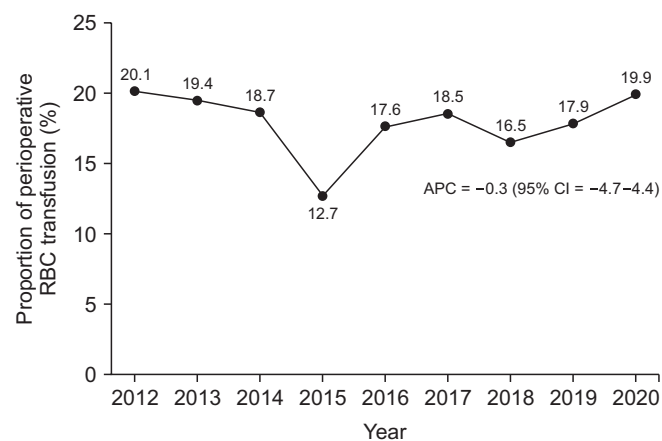
SD, standard deviation; IQR, interquartile range.

among patients undergoing pancreatic cancer surgery each year were evaluated using annual percent change (APC), based on a regression model involving a single regression line fitted to the log scale over a predetermined interval [18]. Temporal trends were further examined, stratified by sex, pancreatic surgery method, and medical institution type. Multivariable logistic regression analysis was used to identify factors independently associated with RBC transfusion, adjusting for the effects of other variables. The variables included in the multivariable logistic regression were: age per 10-year increment, sex, residential area, income, CCI score, time from cancer diagnosis to surgery, pancreatic surgery method, medical institution type where pancreatic surgery was conducted, and year of surgery. Outcomes are reported as odds ratios (ORs) with 95% confidence intervals (CIs). All statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc.).

## RESULTS

The study population comprised 10,473 patients with pancreatic cancer diagnosed between 2012 and 2020 who underwent pancreatic surgery within one-year of diagnosis. Among these, 1,873 (17.9%) received  $\geq 1$  unit of perioperative RBC transfusion. Table 1 presents the sociodemographic characteristics, comorbidity profiles, surgery-related factors, and types of medical institutions for pancreatic surgery according to RBC transfusion status. The median age of the cohort was 65 years, and 55.0% were males. The median interval from cancer diag-

nosis to surgery was nine-days, and pancreaticoduodenectomy was the most frequently performed procedure (61.4%), followed by distal pancreatectomy (29.4%), with 81.5% of these surgeries completed at tertiary hospitals. In comparison to those without RBC transfusion, patients who received transfusions were older, had lower-income, presented with a CCI score of 4–5 or  $\geq 6$ , underwent pancreaticoduodenectomy or total pancreatectomy, and were more frequently treated at secondary medical institu-



**Fig. 1.** Temporal trend of perioperative red blood cell (RBC) transfusion among patients undergoing pancreatic cancer surgery from 2012 to 2020, utilizing National Health Insurance Service (NHIS) data. APC, annual percent change; CI, confidence interval.

tions.

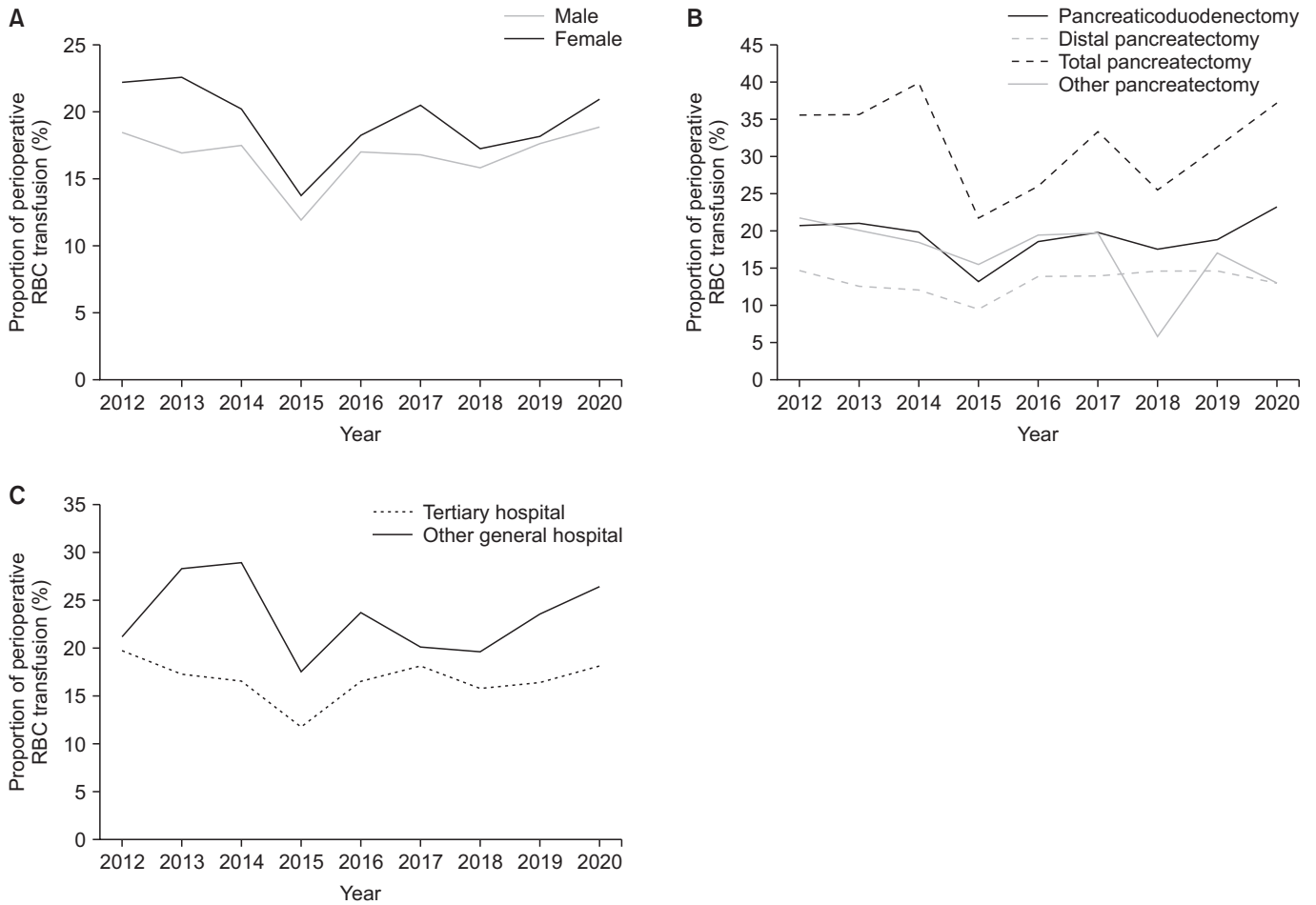
The proportion of patients requiring perioperative RBC transfusions is illustrated in Fig. 1. RBC transfusion rates declined from 20.1% in 2012 to 12.7% in 2015, before rising to 19.9% by 2020. The APC between 2012 and 2015 was  $-13.2\%$  (95% CI,  $-33.1$  to  $12.5$ ), while the APC from 2015 to 2020 was  $6.4\%$  (95% CI,  $-1.5$  to  $14.9$ ). This pattern remained consistent upon stratification by sex (Fig. 2A), surgical method (Fig. 2B), and type of medical institution (Fig. 2C).

For factors linked to perioperative RBC transfusion, after adjustment for other variables, both each 10-year increase in age and female sex compared with male were independently associated with higher odds of RBC transfusion, with ORs of 1.30 (95% CI, 1.24–1.37) and 1.16 (95% CI, 1.05–1.29), respectively (Table 2). Placement in a lower-income quartile, relative to the highest-income quartile, was associated with a higher likelihood of RBC transfusion ( $P_{\text{trend}} = 0.02$ ); specifically, patients in the 2nd and 1st quartiles had 1.25-fold (95% CI, 1.11–1.49) and 1.29-fold (95% CI, 1.11–1.49) increased odds of transfusion. A

higher CCI score was also significantly correlated with a greater probability of RBC transfusion. Compared to a CCI score  $\leq 3$ , patients with a CCI score  $\geq 6$  exhibited increased odds of receiving an RBC transfusion, with an OR of 1.16 (95% CI, 1.02–1.31). Regarding surgical procedures, total pancreatectomy resulted in a 1.91-fold higher likelihood of RBC transfusion compared to pancreaticoduodenectomy (95% CI, 1.56–2.35), while distal pancreatectomy was linked to a 0.65-fold lower likelihood of RBC transfusion (95% CI, 0.57–0.73). Patients treated at general hospitals, when compared with those undergoing pancreatic surgery at tertiary hospitals, had a significantly higher probability of receiving an RBC transfusion (OR, 1.38; 95% CI, 1.22–1.56).

### DISCUSSION

In Korea, 17.8% of patients who underwent pancreatic cancer surgery between 2012 and 2020 received at least 1 unit of RBC transfusion. During this period, the proportion of patients



**Fig. 2.** Temporal trend of perioperative red blood cell (RBC) transfusion for pancreatic cancer surgery according to demographic and clinical characteristics. (A) By sex. (B) According to pancreatic surgery type. (C) According to type of medical institution at which pancreatic surgery was performed.

**Table 2.** Determinants associated with perioperative red blood cell (RBC) transfusion among patients undergoing pancreatic cancer surgery

	Simple analysis	Multiple analysis
Age		
Per 10 year increment	1.32 (1.26–1.38)	1.30 (1.24–1.37)
Sex		
Male	1	1
Female	1.18 (1.06–1.30)	1.16 (1.05–1.29)
Residential area		
Metropolitan	1	1
Non-metropolitan	1.04 (0.94–1.15)	1.00 (0.9–1.11)
Income		
Medical aid	1.41 (1.10–1.80)	1.24 (0.97–1.6)
1st quartile	1.23 (1.07–1.42)	1.29 (1.11–1.49)
2nd quartile	1.16 (1.00–1.34)	1.25 (1.07–1.45)
3rd quartile	1.04 (0.91–1.19)	1.10 (0.96–1.26)
4th quartile	1	1
Charlson comorbidity index score		
≤ 3	1	1
4–5	1.15 (1.02–1.30)	1.00 (0.89–1.13)
≥ 6	1.34 (1.18–1.51)	1.16 (1.02–1.31)
Days from cancer diagnosis to surgery		
< 14	1	1
14–30	0.88 (0.77–1.00)	0.84 (0.74–0.97)
> 30	0.88 (0.89–1.01)	0.91 (0.79–1.05)
Pancreatic surgery methods		
Pancreaticoduodenectomy	1	1
Distal pancreatectomy	0.64 (0.57–0.73)	0.65 (0.57–0.73)
Total pancreatectomy	1.94 (1.58–2.37)	1.91 (1.56–2.35)
Other pancreatectomy	0.84 (0.65–1.07)	0.84 (0.65–1.07)
Medical institution type		
Tertiary hospital	1	1
General hospital	1.53 (1.36–1.72)	1.38 (1.22–1.56)
Year of surgery		
1-year increment	1.00 (0.98–1.02)	1.00 (0.98–1.02)

who received RBC transfusions decreased from 2012 to 2015, then steadily increased, reaching 19.9% by 2020. These trends were observed consistently across sex, type of medical institution, and surgical approach. After controlling for confounding variables, older age at cancer diagnosis, female sex, lower household income, increased comorbidity burden, certain surgical techniques such as total pancreatectomy, and treatment at different types of medical institutions were all associated with higher probabilities of requiring RBC transfusions. This finding is significant because it encompasses all pancreatic surgeries performed on a national scale in the assessment of perioperative RBC transfusion rates.

Pancreatic surgeries have long been linked to significant perioperative morbidity and elevated transfusion rates. A 2015 meta-analysis involving 4,339 patients reported a transfusion rate of 46.5% for pancreatic cancer surgeries, with the range ex-

tending from 19% to 72% [10]. Additional research on patients who underwent pancreatic resection during the early 2010s indicated transfusion rates around 30% [5,7]. More recent investigations demonstrated that with the implementation of PBM, transfusion rates have decreased to under 30% [6,13]. Considerable variability in transfusion rates has been observed, and it is estimated that nearly half of RBC transfusions during pancreatic surgery are unnecessary and could be prevented [19,20]. In comparison with previous data, the present study enrolled a greater number of patients who underwent surgery for pancreatic cancer, yet exhibited a lower rate of RBC transfusion. In Korea, transfusion rates for cardiac surgery, coronary artery bypass procedures, knee arthroplasty, liver transplantation, or kidney transplantation are higher than those reported in other countries [21–23]. Additionally, Korea reported a higher frequency of febrile nonhemolytic transfusion reactions, a com-

mon adverse effect of transfusion, emphasizing the necessity for appropriate blood management strategies, including stricter transfusion practices [21]. Increased recognition of elevated transfusion rates and continued efforts to enhance the appropriateness of blood transfusion may contribute to the reduced transfusion rates observed in major operations such as pancreatic cancer surgery.

A comprehensive evaluation of transfusion pattern changes and the refinement of transfusion guidelines necessitate the implementation of a PBM program. PBM aims to limit transfusion requirements by applying measures such as preoperative hemoglobin optimization, blood-sparing practices, and autologous blood donation [24,25]. This development signifies an ongoing paradigm shift in the field toward more patient-centered and conservative blood management strategies, particularly in the context of pancreatic cancer surgery [12]. Despite these advances, the perioperative transfusion rate in pancreatic cancer surgery in Korea showed little variation and even experienced a slight increase between 2015 and 2020. This pattern persisted regardless of patient demographics, surgical approaches, and institutional APC volumes, with these differences not reaching statistical significance. After adjusting for confounding variables, no significant association was found between RBC transfusion rate and RBC transfusion (OR, 1.0). Although research involving distinct populations and healthcare systems demonstrated a decline in perioperative transfusion rates for pancreatic surgery [6,7,13], this trend was not observed in Korea. The upward trend in transfusion rates noted after 2015 may be partly explained by changes in patient demographics, especially the aging patient population undergoing pancreatic cancer surgery, as well as increased case complexity. The mean age of pancreatic cancer surgery patients rose from 63.3 in 2015 to 64.7 in 2020. Furthermore, limited awareness of PBM concepts within pancreatic surgery may contribute to the persistently unchanged RBC transfusion rates in these procedures. Unlike other oncological diseases where mortality has clinically declined, pancreatic cancer-related mortality remains unchanged, with observed differences lacking statistical significance [26]. The stable prognosis of pancreatic cancer could be related to the continued steadiness in perioperative transfusion rates, or the relationship may be bidirectional.

Among patient-related factors, advanced age at the time of surgery, female sex, increased preoperative comorbidities, and the specific surgical method, were all factors found in this study to increase the likelihood of transfusion, and these have previously been associated with an elevated transfusion rate [5,6,19,27]. This study is the first to demonstrate an association between lower-income level and an increased RBC transfusion rate. In addition to the implementation of PBM leading to reduced intraoperative blood loss, continuing advancements in surgical techniques and devices have substantially contributed to minimizing blood loss during procedures [12,28]. Nevertheless, since PBM is not reimbursed by the NHIS, whereas RBC

transfusion is, patients are required to bear the cost of PBM themselves, which can restrict access, especially for individuals in lower-income groups. Although PBM utilization was not assessable in our study due to its lack of NHIS coverage, expanding insurance reimbursement to include evidence-supported PBM strategies could promote more equitable access—particularly for low-income patients—and should be prioritized in future health policy decisions. As such, insurance coverage for techniques that improve hematopoiesis and limit blood loss is necessary to promote the broader application of PBM in clinical practice [7], which is consistent with our findings.

In addition to patient-related factors, general hospitals reported a higher frequency of RBC transfusions compared to tertiary hospitals. Based on the quality assessment of blood transfusion services by the Health Insurance Review and Assessment Service, tertiary hospitals demonstrate more comprehensive transfusion management systems and provide superior preoperative anemia care [21]. The establishment of a robust blood management system is likely to reduce transfusion rates, underscoring the significance of PBM in pancreatic surgery. Given the clinical complexity associated with pancreatic cancer, centralizing major pancreatic surgeries to tertiary hospitals, particularly those in metropolitan regions, is advisable [29,30], and may potentially reduce the requirement for RBC transfusion.

This study has several limitations. First, because the NHIS data are derived from claims records, detailed information on the use of medical procedures or treatments not reimbursed by the NHIS, as well as the results of laboratory tests, is unavailable. Consequently, crucial elements related to RBC transfusion, such as the use of laparoscopic or robotic surgery and preoperative hemoglobin measurements, were not accessible. Furthermore, our study lacked essential clinical data, including cancer stage, preoperative hemoglobin concentrations, intraoperative blood loss, operative duration, and details on PBM implementation, which could otherwise be obtained by reviewing medical records. Therefore, we could not assess whether transfusions were appropriate for individual cases or directly measure PBM effectiveness. Despite these limitations, leveraging nationwide administrative data enabled us to report overall transfusion trends during pancreatic surgery and investigate potential contributing factors, particularly highlighting the role of PBM. To exclude cases involving prolonged chemotherapy or palliative surgery, we implemented a one-year restriction; nevertheless, a range of disease stages impacting the extent of excision and thereby closely related to transfusion were not accounted for. Instead of focusing on the extent of tumor removal, we classified pancreatic surgery types and observed a higher RBC transfusion rate in patients undergoing total pancreatectomy compared to those receiving pancreaticoduodenectomy. Additionally, the lack of outcome data—such as rates of postoperative complications, recurrence, and survival—prevented assessment of the direct clinical outcomes of

transfusion. Although earlier research has shown correlations between transfusion and unfavorable oncologic outcomes—such as higher recurrence rates and decreased survival—in various cancer surgeries [31,32], our analysis did not explore these specific associations. Furthermore, while our study underscored the significance of PBM, we could not directly measure its effectiveness because PBM was not reimbursed by the NHIS. Despite these constraints, the principal strength of this study is its ability to capture a nationwide cohort of pancreatic cancer surgeries conducted over nine-years within a real-world context in South Korea. This broad scope provides valuable perspectives on RBC transfusion patterns as well as associated patient-level and institution-level determinants.

In conclusion, from 2012 to 2020, of 10,473 patients diagnosed with pancreatic cancer who underwent surgery within 1 year, the perioperative RBC transfusion rate was 17.8%, which was lower than reported in prior studies. However, after declining from 2012 to 2015, the transfusion rate subsequently increased through 2020. The type of pancreatic surgery was a primary factor related to RBC transfusion, though both patient-level and institutional factors also showed significant associations with perioperative RBC transfusion in pancreatic cancer surgery. Notably, increased RBC transfusion rates were observed among lower-income patients (medical aid) and in the context of newly developed techniques not yet reimbursed by the NHIS, which aim to reduce transfusion rates. Thus, expanding NHIS reimbursement to include PBM strategies, rather than covering only the transfusion itself, is recommended in Korea. Incorporating PBM into the NHIS would facilitate assessment of implementation and effectiveness across PBM strategies and support the development of evidence-based transfusion policies. Further research is needed to determine the impact of PBM—which remains underutilized in pancreatic surgery—on transfusion use and postoperative outcomes.

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## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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Conceptualization: SH, YKJ, DC, BP. Data curation: SH, BP. Methodology: SH, BP. Validation: SK, JY. Writing – original draft: SH, BP. Writing – review & editing: SH, YKJ, SK, JY, DC, BP.

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