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Chronic Kidney Disease Increases Risk of Delayed Post-Polypectomy Bleeding: A Large-Scale Propensity Score-Matched Analysis

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Keywords: bleeding risk factors | chronic kidney disease | colonoscopy | delayed post-polypectomy bleeding | polypectomy | propensity score matching

ABSTRACT

Background: The association between delayed post-polypectomy bleeding and chronic kidney disease remains unclear.

Objective: This study investigated whether patients with chronic kidney disease are at an increased risk of delayed post-polypectomy bleeding.

Methods: This cohort study included patients who underwent colonoscopy and polypectomy in Korea between 2005 and 2022. We assessed various covariates, including patient-, polyp-, and procedure-related factors, using propensity score matching and inverse probability of treatment weighting to determine the impact of chronic kidney disease on delayed post-polypectomy bleeding risk.

Results: Out of 21,562 patients, 16,591 with 41,014 polyps were included in the analysis. Of these, 2057 (12.4%) had chronic kidney disease, with 894 in early-stage (stages 1 and 2) and 1163 in advanced-stage (stages 3–5). There were 14,534 individuals without chronic kidney disease. After propensity score matching, the risk of delayed post-polypectomy bleeding in patients with chronic kidney disease was significantly higher than that in the non-chronic kidney disease group (OR 1.80, CI 1.12–2.89, $p = 0.01$). The risk increased with chronic kidney disease stage (OR 2.38, 95% CI 1.01–5.64 for early stage; OR 2.80, 95% CI 1.20–6.51 for advanced stage, all $p < 0.05$). The results remained robust after inverse probability analysis.

Conclusions: Chronic kidney disease is an independent risk factor for delayed post-polypectomy bleeding, even in the early stages. The risk correlates with the chronic kidney disease stage. Meticulous attention is imperative during polypectomy for all patients with chronic kidney disease, including those in the early stages.

Abbreviations: ANOVA, analysis of variance; BMI, body mass index; CFP, cold forceps polypectomy; CI, confidence interval; CKD, chronic kidney disease; CRC, colorectal cancer; CSP, cold snare polypectomy; DM, diabetes mellitus; DOACs, direct oral anticoagulants; DPPB, delayed post-polypectomy bleeding; eGFR, estimated glomerular filtration rate; EMR, endoscopic mucosal resection; ESD, endoscopic submucosal dissection; ESRD, end-stage renal disease; INR, international normalized ratio; IPPB, immediate post-polypectomy bleeding; IPTW, inverse probability of treatment weighting; NSAIDs, nonsteroidal anti-inflammatory drugs; OR, odds ratio; PPB, post-polypectomy bleeding; PSM, propensity score matching; SCRAP, Severance Clinical Research Analysis Portal; SMD, standardized mean difference.

Summary

- Summarise the established knowledge on this subject
  - Patients with chronic kidney disease (CKD) have an elevated risk of developing colorectal cancer or colorectal adenomas, underscoring the importance of colonoscopy and colonoscopic polypectomy for early detection and treatment.
  - Although concerns about the safety of colonoscopic polypectomy in patients with CKD are increasing, the association between delayed post-polypectomy bleeding (DPPB) and CKD remains unclear.
- What are the significant and/or new findings of this study?
  - CKD is an independent risk factor for DPPB, even in its early stage, and that the level of risk correlated with CKD stage.
  - Careful monitoring of bleeding is necessary for at least 1 month after colonoscopic polypectomy across all CKD stages.

1 | Introduction

Colorectal cancer (CRC) is the third most prevalent malignancy worldwide and the second most common cause of cancer-related mortality, constituting approximately 10% of all cancer incidences [1]. Early detection and treatment of CRC offer significant potential to reduce morbidity and mortality, presenting a viable opportunity for a cure [2–4]. The role of colonoscopy with polypectomy is pivotal in mitigating cancer-related mortality by early detection of CRC and removal of precancerous lesions such as adenomas [5–7]. Although colonoscopic polypectomy is generally considered a safe and effective procedure, it may cause potential complications, including post-polypectomy bleeding (PPB), post-polypectomy syndrome, and perforation. Importantly, the prevalence of PPB as a common major complication is as high as 6.5% in the general population [8]. PPB is categorised into immediate PPB (IPPB) and delayed PPB (DPPB). DPPB is less frequent, with an overall incidence of DPPB in colorectal polypectomy ranging from 0.3% to 1.2% [9, 10]. However, DPPB poses a more serious risk due to its unpredictable onset and requires intensive management, including hospitalisation, endoscopic haemostatic procedures, blood transfusion, and occasional colectomy [11]. Thus, identifying the risk factors for DPPB is crucial to prevent complications and improve outcomes in patients with a high risk of bleeding.

Chronic kidney disease (CKD) is defined as a progressive loss of renal function, measured by the level of albuminuria and the decline in the estimated glomerular filtration rate (eGFR) [12]. According to the Global Burden of Disease study, the global prevalence of CKD increased by 33% between 1990 and 2017, making it one of the fastest-growing causes of death worldwide [13]. CKD significantly increases the risk of various adverse health outcomes [14] and is linked to numerous atherosclerotic cardiovascular diseases. The risk of these complications escalates as kidney function declines, leading to poorer prognoses and increased healthcare burdens [15, 16].

In addition to cardiovascular risks, patients with CKD also have an elevated risk of developing CRC or colorectal adenoma, likely due to shared risk factors such as higher body mass index (BMI), advanced age, and male sex, rather than CKD itself being a direct risk factor [17–19]. This elevated cancer risk underscores the importance of colonoscopy and colonoscopic polypectomy for the early detection and treatment of CRC and adenoma in patients with CKD. However, colonoscopy in patients with CKD is associated with a higher risk of complications, notably PPB [20–25]. This increased bleeding risk poses significant challenges in the management of patients with CKD and raises concerns regarding the safety of colonoscopic polypectomy in these populations. However, previous studies did not focus specifically on patients with CKD or included only those with end-stage renal disease (ESRD) [21, 25, 26]. In addition, most studies failed to fully account for various medications, comorbidities, laboratory findings, and endoscopic factors, which can lead to distorted and exaggerated conclusions [21, 23–25, 27, 28]. Furthermore, to our knowledge, no studies have evaluated whether early- and advanced-stage CKD contributes to the risk of DPPB. More comprehensive evidence is required to clarify the risk of colonoscopic PPB in these patients.

Thus, this study aimed to investigate the association between CKD and DPPB risk using a large cohort of data. It employed propensity score matching (PSM) and inverse probability of treatment weighting (IPTW) to mitigate confounding factors and ensure robust results.

2 | Materials and Methods

2.1 | Data Source

Data were collected using the Severance Clinical Research Analysis Portal (SCRAP) system. SCRAP searches and analyses clinical data according to specific criteria and prospectively collects longitudinal data. Anonymised data were extracted from an operational database containing information on more than 6,500,000 patients from November 2005 to the present. SCRAP allows for extracting patient sociodemographic factors, history, family history, medication, diagnoses, surgeries, clinical observations, imaging (endoscopic and radiologic), laboratory findings, histopathological results, and forms using registration and visit numbers. Additionally, we conducted a comprehensive review of the medical records of patients who underwent colorectal polypectomy, including CKD and non-CKD, at Severance Hospital and Yongin Severance Hospital, Korea, to further substantiate the findings. This study was performed in accordance with the ethical guidelines of the 1975 Declaration of Helsinki and was approved by the Institutional Review Board of Yongin Severance Hospital (IRB No. 9-2022-0116; date of registration, October 21, 2022). Informed consent was not required owing to the retrospective study design.

2.2 | Study Design and Patients

This was a two-centre retrospective cohort analysis involving 21,562 patients who underwent colonoscopy with polypectomy

between November 2005 and June 2022. The inclusion criteria were as follows: (1) adults aged ≥ 18 years, and (2) patients who underwent colonoscopic polypectomy for colorectal polyps. The exclusion criteria were as follows: (1) age < 18 years, (2) uncertain diagnosis of CKD, (3) on dialysis (ESRD), (4) insufficient clinical and laboratory information, (5) combined inflammatory bowel disease, and (6) familial adenomatous polyposis. To evaluate the risk of DPPB associated with CKD, patients without CKD who underwent polypectomy were matched with patients with CKD based on CKD stage in a 1:1:1 (non-CKD: early-stage CKD: advanced-stage CKD) ratio using PSM.

The CKD stage is categorised using the Kidney Disease: Improving Global Outcomes criteria [29], and eGFR was calculated using the Chronic Kidney Disease Epidemiology Collaboration equation [30] for early-stage and advanced-stage CKD. Early-stage CKD includes stages 1 and 2 (eGFR ≥ 60 mL/min/1.73 m^2 with albuminuria), while advanced-stage CKD encompasses stages 3, 4 (15 ≤ eGFR < 60 mL/min/1.73 m^2 with/without albuminuria), and 5 (eGFR < 15 mL/min/1.73 m^2 without dialysis) [12]. All eligible patients discontinued antiplatelets 5–7 days before undergoing colorectal polypectomy, and direct oral anticoagulants (DOACs) were withheld 2 days before the procedure. Depending on the patient's condition, the anticoagulants were replaced with heparin as part of a tailored treatment approach. After colorectal polypectomy, the endoscopist made individualised decisions regarding the timing for resuming antiplatelet or anticoagulant therapy, guided by previously established guidelines [31–33].

Colonoscopic polypectomies were performed after standard bowel preparation using two or 4 L of polyethylene glycol electrolyte solution. During conscious sedation endoscopy, midazolam was administered intravenously at a dose of 0.05–0.07 mg/kg, with an additional 1–3 mg of midazolam or 10–20 mg of propofol given as needed to achieve moderate sedation, according to the endoscopist's judgement. All polypectomies were performed by a gastroenterologist using high-definition conventional colonoscopy (CF H260AL, CF H260AI, CF-H290L, CF-HQ290I, GIF-HQ290, and GIF-HQ290; Olympus Optical, Tokyo, Japan). All patients were followed up at an outpatient visit within 1 month after the polypectomy to confirm histopathological results, check clinical symptoms and vital signs, and perform additional serum blood tests as necessary.

2.3 | Covariates

2.3.1 | Patient-Related Variables

Patient-related factors, including age, sex, BMI, past medical history, laboratory findings, and medication use, specifically antiplatelets (aspirin, clopidogrel, prasugrel, and ticagrelor), anticoagulants (warfarin and DOACs), nonsteroidal anti-inflammatory drugs (NSAIDs), and corticosteroids, were carefully collected and analysed. Anti-thrombotics were promptly resumed based on guidelines, although the exact timing varied according to the clinical judgement of individual physicians. Comorbidities included hypertension, diabetes mellitus (DM), liver cirrhosis or chronic liver disease, cardiovascular disease, cerebrovascular disease, and various other cancers. The following laboratory findings were also examined for each patient: haemoglobin level, platelet count, and coagulation parameters, such as prothrombin time, partial thromboplastin time, and international normalised ratio (INR), encompassing all factors related to haemostasis.

2.3.2 | Polyp-Related Variables

Polyp-related factors, such as polyp size, morphology, location, and histopathological results obtained during colorectal polypectomy were also meticulously assessed. The polyp distribution was categorised as right (caecum, ascending colon, and transverse colon), left (descending colon and sigmoid colon), or rectal. Each polyp size was estimated using open biopsy forceps with a fully open gap of 7 mm. The polyps were classified using the modified criteria of the Japanese Research Society Classification [34]. Polyp morphology was further analysed based on the presence or absence of a stalk, classifying the polyps into pedunculated polyps including subpedunculated lesions (Isp and Ip), and nonpedunculated polyps including sessile lesions (Is), flat polyps (II) and laterally spreading tumours. Histopathologically, resected polyps were categorised into two groups: adenomatous, which includes tubular, tubulovillous, villous, and carcinoma in situ; and non-adenomatous, encompassing serrated, hyperplastic, inflammatory, and mixed types.

A representative polyp was selected for each patient, prioritizing clinical significance and consistency with study objectives to match the heterogeneous CKD and non-CKD groups for PSM and IPTW [35–37]. Selection was based on a hierarchical approach, starting with the largest polyp, followed by resection methods (ESD, EMR, CSP, CFP) and polyp morphology (Ip, Isp, LST, Is, IIa).

2.3.3 | Procedure-Related Variables

Procedure-related variables were thoroughly analysed, including the endoscopic resection method, duration of the procedure, endoscopist experience, quality of bowel preparation, preventive haemostasis, and IPPB. Endoscopic resection techniques were based on polyp size and morphology at the practitioner's discretion. Cold forceps polypectomy (CFP) or cold snare polypectomy (CSP) was employed for small polyps (less than 10 mm), endoscopic mucosal resection (EMR) was performed for larger polyps (10–20 mm), and endoscopic submucosal dissection (ESD) was applied to very large polyps (greater than 20 mm) that EMR could not effectively remove or those with a potential for high-grade dysplasia or malignancy. Endoscopic resection techniques were categorised based on electrocautery and submucosal injections (CFP and CSP vs. EMR and ESD). During colorectal polypectomy, the total procedure time encompasses the time taken to reach the caecum or terminal ileum during insertion and the time for withdrawal from the caecum to the rectum until the examination concludes. Endoscopist experience was classified as attending staff with

two or more years of experience or trainees with less than 2 years of experience. Subspeciality certification requires rigorous training, including 2000 diagnostic and 100 therapeutic procedures over two years, ensuring advanced proficiency. Bowel preparation quality for colonoscopy is categorised into four groups based on the Aronchick bowel preparation scale: poor, adequate, good, and excellent [38, 39]. IPPB is defined as bleeding in an oozing pattern that persists for more than 1–5 min during polypectomy despite continued irrigation [40, 41]. In cases where PPB was a concern, the practitioner employed preventive haemostatic techniques, such as hemoclipping, electrocoagulation, or epinephrine injection, used singly or combined, based on clinical judgement.

2.4 | Outcomes

The primary outcome was the association between CKD and the risk of colonoscopic DPPB. DPPB was defined as the occurrence of one or more episodes of haematochezia requiring management with endoscopic haemostatic procedures, resulting in emergency attendance, hospitalization, or reintervention within 30 days after polypectomy [42]. The secondary outcome was the risk of DPPB depending on the CKD stage.

2.5 | Statistical Analysis

Means and standard deviations are presented for continuous variables, and frequencies and proportions for categorical variables. In general, for continuous variables, mean comparisons between independent non-CKD and CKD stage groups were assessed using a one-way analysis of variance (ANOVA), and mean comparisons between the non-CKD and CKD groups were assessed using independent two-sample *t*-tests based on features that satisfied the normal distribution, including the results of the Shapiro–Wilk test. For categorical variables, the results are presented using the chi-square test or Fisher's exact test for both types of comparisons. Owing to the nature of retrospective studies, imbalances in baseline characteristics between groups can directly affect the results; therefore, we attempted to overcome this by utilising PSM, a special statistical bias correction method. In particular, by applying the PSM method to multiple groups, the study was designed to allow comparisons between groups with the same number of people, while all covariates were homogeneous (comparison of non-CKD and early-stage CKD, comparison of non-CKD and advanced-stage CKD, and comparison of early-stage CKD and advanced-stage CKD). In addition, we simultaneously applied the IPTW method, which considers the weight of matching while utilising all included participants. We presented the results to prove the validity of our research from various angles. For both methods, we calculated the standardised mean difference (SMD) to check for balance between groups, and an SMD of 0.2 or less was considered adequate [43–45]. The univariate and multivariate logistic regression, PSM, and IPTW results are presented. All statistical analyses were performed using SAS V9.4 software (SAS Institute Inc., Cary, NC, USA).

3 | Results

3.1 | Study Flow and Patients

Of the 21,562 participants, 41,014 polyps in 16,591 patients met the inclusion criteria. The baseline characteristics of the study population are shown in Table 1. There were 2057 (12.4%) patients in the CKD group and 14,534 (87.6%) in the non-CKD group. In the CKD cohort, 894 patients (43.5%) were classified as having early-stage CKD (stages 1 and 2), whereas 1163 patients (56.5%) were diagnosed with advanced-stage CKD (stages 3–5). A representative polyp was selected from multiple polyps removed from a single patient based on size, endoscopic resection method, and morphology. After excluding unmatched individuals through PSM, 5173 polyps from 1713 individuals were analysed in both cohorts. After applying the IPTW, 119,804 polyps from 46,486 patients were included in the analysis (Table 1). The flowchart of this study is depicted in Figure 1.

The potential confounders for PPB, including factors correlated with bleeding, such as medications (antiplatelets, anticoagulants, NSAIDs, and corticosteroids), laboratory findings (haemoglobin level, platelet count, prothrombin time, partial thromboplastin time, and INR), comorbidities, polyp-related factors (size, morphology, location, and histopathological results), and procedure-related factors (resection method, duration of the procedure, endoscopist's experience, quality of bowel preparation, preventive haemostasis, and IPPB), were well matched using PSM and IPTW. The balance of covariates between the cohorts is presented in Figure S1. After propensity score-matched analysis, all covariates were well-balanced (i.e., SMDs were < 0.2). The standard deviation for all characteristics after IPTW adjustment was also less than 0.2, indicating that the weighted populations were comparable.

3.2 | Risk Factors for DPPB

In univariate analysis, several factors significantly increased the risk of DPPB (Table 2). Age, male sex, low BMI, hypertension, DM, cardiovascular and cerebrovascular disease, CKD, use of antiplatelets and anticoagulants, lower haemoglobin levels, and prolonged prothrombin time or INR were significantly associated with increased DPPB risk (all $p < 0.05$). Polyp-related factors, including the number of polyps, larger polyp size, and pedunculated polyps, significantly increased the risk of DPPB (all $p < 0.05$). Procedure-related factors such as the resection method (EMR or ESD), extended procedure times, IPPB, and implementation of preventive haemostasis also increased the risk of DPPB (all $p < 0.05$). Multivariate analysis revealed that the risk of DPPB was significantly increased by factors such as DM (odds ratio [OR] 1.49, 95% confidence interval [CI] 1.11–2.00; $p < 0.01$), CKD (OR 1.44, 95% CI 1.05–1.98; $p = 0.03$), use of anticoagulants (OR 2.32, 95% CI 1.23–4.38; $p = 0.01$), a higher number of polyps (OR 1.05, 95% CI 1.02–1.09; $p < 0.01$), larger polyp sizes (20–30 mm: OR 8.45, 95% CI 5.33–13.41; $p < 0.01$, > 30 mm: OR 11.05, 95% CI 5.57–21.93; $p < 0.01$), pedunculated polyps (OR 1.35, 95% CI 1.04–1.75; $p = 0.02$), and extended procedure time (OR 1.01, 95% CI 1.00–1.01; $p = 0.04$) (Table 2).

TABLE 1 | Baseline characteristics of the study population.

Variables	Before (n = 16,591)				After PSM[a] (n = 1713)				After IPTW[a] (n = 46,486)			
			CKD (n = 2,057, 12.4%)				CKD (n = 1,142, 66.7%)				CKD (n = 29,848, 64.2%)	
	All (41,014 polyps in 16,591 patients)	Non-CKD n = 14,534 (87.6%)	Early CKD n = 894 (43.5%)	Advanced CKD n = 1163 (56.5%)	All (5173 polyps in 1713 patients)	Non-CKD n = 571 (33.3%)	Early CKD n = 571 (50.0%)	Advanced CKD n = 571 (50.0%)	All (119,804 polyps in 46,486 patients)	Non-CKD n = 16,638 (35.8%)	Early CKD n = 15,875 (53.2%)	Advanced CKD n = 13,973 (46.8%)
Patient-related factor												
Demographic variables												
Age, years	62.2 ± 11.9	61.4 ± 11.7	62.8 ± 12.3	70.9 ± 9.6	65.9 ± 11.2	62.6 ± 12.3	67.6 ± 10.2	67.6 ± 10.2	62.8 ± 20	62.2 ± 12.6	62.4 ± 52.6	64.1 ± 39.9
Male	9832 (59.3%)	8520 (58.6%)	549 (61.4%)	763 (65.6%)	1073 (62.6%)	343 (60.1%)	361 (63.2%)	369 (64.6%)	28,746 (61.8%)	9882 (59.4%)	10,169 (64.1%)	8695 (62.2%)
Body mass index, kg/m^2	23.8 ± 3.4	23.8 ± 3.3	23.8 ± 3.9	24.1 ± 3.4	24.0 ± 3.7	24.0 ± 3.7	24.0 ± 3.9	24.0 ± 3.5	24.0 ± 5.7	23.8 ± 3.4	24.0 ± 14.8	24.2 ± 11.9
Comorbidities												
Hypertension	3635 (21.9%)	2717 (18.7%)	306 (34.2%)	612 (52.6%)	705 (41.2%)	191 (33.5%)	257 (45%)	257 (45%)	12,240 (26.3%)	3676 (22.1%)	4049 (25.5%)	4516 (32.3%)
Diabetes mellitus	2854 (17.2%)	2085 (14.4%)	268 (30%)	501 (43.1%)	591 (34.5%)	176 (30.8%)	207 (36.3%)	208 (36.4%)	8865 (19.1%)	2884 (17.3%)	3087 (19.5%)	2893 (20.7%)
Liver cirrhosis or chronic liver disease	767 (4.6%)	676 (4.7%)	61 (6.8%)	30 (2.6%)	99 (5.8%)	54 (9.5%)	24 (4.2%)	21 (3.7%)	1966 (4.2%)	768 (4.6%)	680 (4.3%)	519 (3.7%)
Cardiovascular and cerebrovascular	1258 (7.6%)	1008 (6.9%)	111 (12.4%)	139 (12.0%)	217 (12.7%)	75 (13.1%)	71 (12.4%)	71 (12.4%)	3910 (8.4%)	1269 (7.6%)	1347 (8.5%)	1294 (9.3%)
Cancers	2842 (17.1%)	2663 (18.3%)	112 (12.5%)	67 (5.8%)	165 (9.6%)	77 (13.5%)	42 (7.4%)	46 (8.1%)	7113 (15.3%)	2837 (17.1%)	2800 (17.6%)	1476 (10.6%)
Medications												
Antiplatelets	704 (4.2%)	481 (3.3%)	89 (10.0%)	134 (11.5%)	172 (10.0%)	54 (9.5%)	60 (10.5%)	58 (10.2%)	2347 (5.1%)	714 (4.3%)	742 (4.7%)	892 (6.4%)
Anticoagulants	265 (1.6%)	168 (1.2%)	44 (4.9%)	53 (4.6%)	98 (5.7%)	33 (5.8%)	32 (5.6%)	33 (5.8%)	984 (2.1%)	273 (1.6%)	315 (2.0%)	395 (2.8%)
NSAIDs and corticosteroids	1496 (9.0%)	1119 (7.7%)	203 (22.7%)	174 (15.0%)	362 (21.1%)	135 (23.6%)	119 (20.8%)	108 (18.9%)	4650 (10.0%)	1522 (9.2%)	1607 (10.1%)	1521 (10.9%)
Laboratory findings												
Haemoglobin, g/dL	13.5 ± 2.0	13.7 ± 1.8	12.3 ± 2.4	12.0 ± 2.4	12.3 ± 2.3	12.4 ± 2.3	12.2 ± 2.3	12.2 ± 2.3	13.5 ± 3.6	13.5 ± 2.1	13.6 ± 9.3	13.4 ± 7.7
Platelet count, 10^9/L	236.0 ± 74.5	235.8 ± 70.3	262.0 ± 114.9	218.2 ± 80.5	244.9 ± 94.6	262.6 ± 99.6	235.1 ± 91.9	237.1 ± 89.6	236.8 ± 132.5	236 ± 79.3	236.7 ± 353.8	237.9 ± 275.7
Prothrombin	1.0 ± 0.2	1.0 ± 0.2	1.1 ± 0.2	1.0 ± 0.3	1.1 ± 0.4	1.1 ± 0.4	1.1 ± 0.2	1.1 ± 0.4	1.0 ± 0.4	1.0 ± 0.2	1.0 ± 0.7	1.0 ± 0.9

(Continues)

TABLE 1 | (Continued)

Variables	Before (n = 16,591)				After PSM[a] (n = 1713)				After IPTW[a] (n = 46,486)			
			CKD (n = 2,057, 12.4%)				CKD (n = 1,142, 66.7%)				CKD (n = 29,848, 64.2%)	
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time, INR												
aPTT, sec	31.4 ± 5.8	31.3 ± 5.7	31.8 ± 6.6	31.6 ± 6.2	31.8 ± 6.5	32.1 ± 7.3	31.6 ± 6.2	31.7 ± 6.1	31.4 ± 8.8	31.4 ± 6.1	31.5 ± 21.7	31.3 ± 17.2
Polyp-related factors												
Polyp number per patient	2.5 ± 2.4	2.4 ± 2.3	2.8 ± 2.9	3.1 ± 2.9	3.0 ± 3.1	3.0 ± 3.2	3.1 ± 3.2	2.9 ± 2.7	2.6 ± 4.2	2.5 ± 2.6	2.7 ± 11.0	2.6 ± 8.4
Polyp size (mm)	5.7 ± 4.1	5.6 ± 3.9	6.3 ± 4.9	6.5 ± 4.8	6.4 ± 4.8	6.3 ± 4.6	6.6 ± 5.3	6.3 ± 4.3	5.8 ± 7.0	5.7 ± 4.4	5.9 ± 18.5	5.8 ± 14.0
Polyp size												
< 10 mm	14,561 (87.8%)	12,863 (88.5%)	744 (83.2%)	954 (82.0%)	1403 (82.1%)	471 (82.6%)	464 (81.3%)	468 (82.5%)	40,356 (86.8%)	14,595 (87.7%)	13,610 (85.7%)	12,150 (87.0%)
10–20 mm	1712 (10.3%)	1408 (9.7%)	130 (14.5%)	174 (15.0%)	260 (15.2%)	79 (13.9%)	93 (16.3%)	88 (15.5%)	5248 (11.3%)	1702 (10.2%)	2024 (12.8%)	1523 (10.9%)
20–30 mm	241 (1.5%)	201 (1.4%)	13 (1.5%)	27 (2.3%)	31 (1.8%)	15 (2.6%)	8 (1.4%)	8 (1.4%)	660 (1.4%)	259 (1.6%)	142 (0.9%)	260 (1.9%)
> 30 mm	77 (0.5%)	62 (0.4%)	7 (0.8%)	8 (0.7%)	14 (0.8%)	5 (0.9%)	6 (1.1%)	3 (0.5%)	222 (0.5%)	82 (0.5%)	100 (0.6%)	41 (0.3%)
Morphology												
Non-pedunculated	12,251 (74.5%)	10,839 (75.2%)	616 (69.8%)	796 (68.9%)	1174 (69.2%)	392 (68.9%)	386 (68.7%)	396 (70.0%)	34,602 (74.4%)	12,407 (74.6%)	11,674 (73.5%)	10,521 (75.3%)
Pedunculated	4193 (25.5%)	3567 (24.8%)	267 (30.2%)	359 (31.1%)	523 (30.8%)	177 (31.1%)	176 (31.3%)	170 (30.0%)	11,884 (25.6%)	4231 (25.4%)	4202 (26.5%)	3452 (24.7%)
Location												
Right colon	8831 (53.4%)	7739 (53.5%)	455 (51.0%)	637 (55.1%)	903 (52.9%)	286 (50.3%)	306 (53.7%)	311 (54.8%)	24,594 (52.9%)	8932 (53.7%)	7971 (50.2%)	7692 (55.1%)
Left colon	5858 (35.4%)	5089 (35.2%)	348 (39.0%)	421 (36.4%)	639 (37.4%)	218 (38.3%)	212 (37.2%)	209 (36.8%)	16,621 (35.8%)	5862 (35.2%)	5976 (37.6%)	4782 (34.2%)
Rectum	1840 (11.1%)	1652 (11.4%)	90 (10.1%)	98 (8.5%)	165 (9.7%)	65 (11.4%)	52 (9.1%)	48 (8.5%)	5272 (11.3%)	1844 (11.1%)	1929 (12.2%)	1499 (10.7%)
Histopathologic results												
Non-adenomatous	3219 (34.9%)	2845 (35.8%)	146 (27.4%)	228 (30.3%)	270 (25.8%)	80 (24.5%)	88 (24.5%)	102 (28.1%)	8558 (18.4%)	3210 (19.3%)	2977 (18.8%)	2371 (17.0%)

(Continues)

TABLE 1 | (Continued)

Variables	Before (n = 16,591)				After PSM[a] (n = 1713)				After IPTW[a] (n = 46,486)			
			CKD (n = 2,057, 12.4%)				CKD (n = 1,142, 66.7%)				CKD (n = 29,848, 64.2%)	
	All (41,014 polyps in 16,591 patients)	Non-CKD n = 14,534 (87.6%)	Early CKD n = 894 (43.5%)	Advanced CKD n = 1163 (56.5%)	All (5173 polyps in 1713 patients)	Non-CKD n = 571 (33.3%)	Early CKD n = 571 (50.0%)	Advanced CKD n = 571 (50.0%)	All (119,804 polyps in 46,486 patients)	Non-CKD n = 16,638 (35.8%)	Early CKD n = 15,875 (53.2%)	Advanced CKD n = 13,973 (46.8%)
Adenomatous	6004 (65.1%)	5093 (64.2%)	387 (72.6%)	524 (69.7%)	778 (74.2%)	246 (75.5%)	271 (75.5%)	261 (71.9%)	37,928 (81.6%)	13,428 (80.7%)	12,898 (81.3%)	11,602 (83.0%)
Procedure-related factors												
Resection method												
Cold (CFP, CSP)	11,952 (72.7%)	10,584 (73.4%)	585 (66.9%)	783 (67.9%)	1115 (65.9%)	373 (65.7%)	366 (65.7%)	376 (66.2%)	33,875 (72.9%)	12,137 (72.9%)	11,436 (72.0%)	10,302 (73.7%)
Hot (EMR, ESD)	4491 (27.3%)	3831 (26.6%)	290 (33.1%)	370 (32.1%)	578 (34.1%)	195 (34.3%)	191 (34.3%)	192 (33.8%)	12,611 (27.1%)	4502 (27.1%)	4439 (28.0%)	3671 (26.3%)
Procedure time, min	27.9 ± 16.4	27.5 ± 15.3	30.9 ± 28.8	30.7 ± 16.7	31.0 ± 20.3	31.5 ± 26.4	31.3 ± 16.9	30.3 ± 16	28.0 ± 26.4	27.9 ± 17.0	28.5 ± 68.4	27.6 ± 52.1
Endoscopist experience												
Trainee	9826 (59.2%)	8438 (58.1%)	652 (72.9%)	736 (63.3%)	1224 (71.5%)	419 (73.4%)	400 (70.1%)	405 (70.9%)	27,663 (59.5%)	9849 (59.2%)	9305 (58.6%)	8509 (60.9%)
Experienced	6764 (40.8%)	6095 (41.9%)	242 (27.1%)	427 (36.7%)	489 (28.6%)	152 (26.6%)	171 (30.0%)	166 (29.1%)	18,823 (40.5%)	6789 (40.8%)	6571 (41.4%)	5464 (39.1%)
Bowel preparation												
Excellent, good	13,975 (84.3%)	12,348 (85.0%)	716 (80.1%)	911 (78.3%)	1367 (79.8%)	454 (79.5%)	453 (79.3%)	460 (80.6%)	38,670 (83.2%)	13,982 (84%)	13,053 (82.2%)	11,635 (83.3%)
Adequate, poor	2610 (15.7%)	2180 (15.0%)	178 (19.9%)	252 (21.7%)	346 (20.2%)	117 (20.5%)	118 (20.7%)	111 (19.4%)	7816 (16.8%)	2656 (16%)	2822 (17.8%)	2338 (16.7%)
Preventive haemostasis	1539 (9.3%)	1252 (8.6%)	108 (12.2%)	179 (15.4%)	234 (13.7%)	77 (13.5%)	80 (14.1%)	77 (13.5%)	42,155 (90.7%)	16,391 (98.5%)	15,554 (98.0%)	13,672 (97.9%)
Immediate post-polypectomy bleeding	917 (5.6%)	776 (5.4%)	66 (7.5%)	75 (6.5%)	121 (7.2%)	43 (7.7%)	44 (7.8%)	34 (6.0%)	2528 (5.5%)	939 (5.7%)	957 (6.1%)	633 (4.6%)
Delayed post-polypectomy bleeding	276 (1.7%)	205 (1.4%)	25 (2.8%)	46 (4.0%)	44 (2.6%)	7 (1.2%)	17 (3.0%)	20 (3.5%)	869 (1.9%)	247 (1.5%)	321 (2.0%)	300 (2.1%)

Note: Variables are expressed as mean ± SD or n (%).

Abbreviations: aPTT, activated partial thromboplastin time; CFP, Cold forceps polypectomy; CKD, chronic kidney disease; CSP, cold snare polypectomy; EMR, endoscopic mucosal resection; ESD, endoscopic submucosal dissection; INR, international normalized ratio; IPTW, inverse probability of treatment weighting; NSAIDs, nonsteroidal anti-inflammatory drug; PSM, propensity score matching; SD, standard deviation.

[a]PSM & IPTW variables: age, sex, body mass index, hypertension, diabetes mellitus, liver cirrhosis or chronic liver disease, cardiovascular and cerebrovascular disease, cancers, antiplatelets, anticoagulants, NSAIDs and corticosteroids, haemoglobin, platelet count, prothrombin time, aPTT, polyp number per patient, polyp size (mm), polyp size ≥10 mm, morphology, location, histopathologic results, resection method, procedure time, insertion time, withdrawal time, endoscopist experience, bowel preparation, preventive haemostasis and immediate post-polypectomy bleeding.

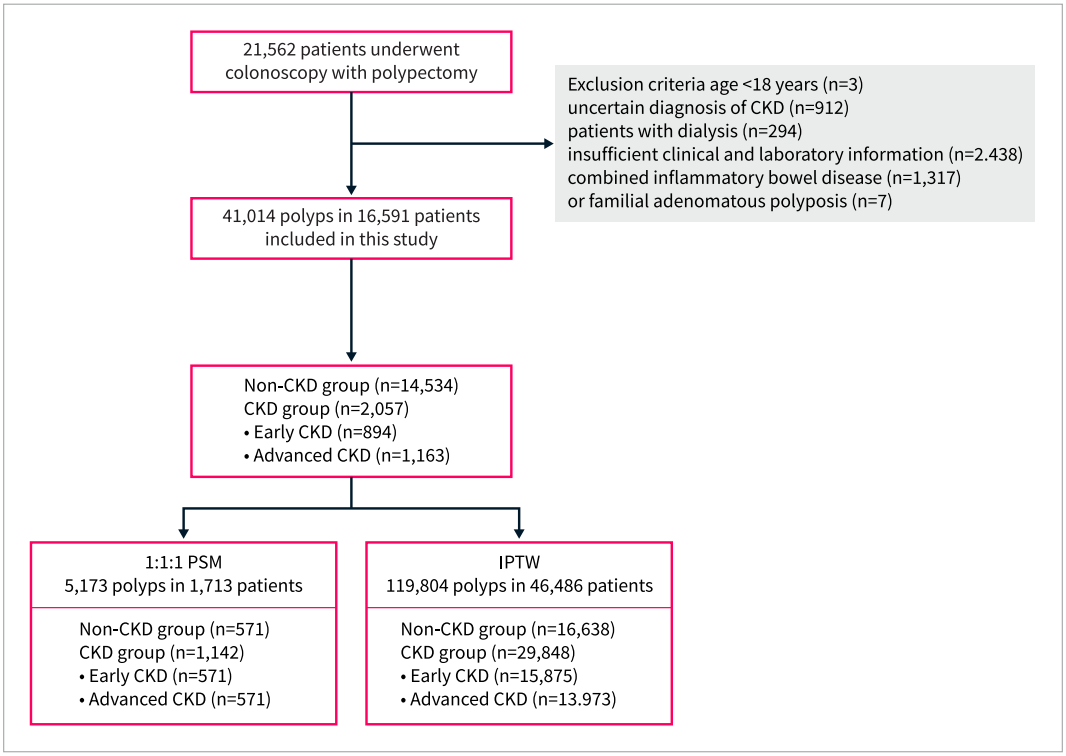

FIGURE 1 | Study flow chart. Of the 21,562 patients, 16,591 patients with 41,014 polyps met the inclusion criteria. The CKD group comprised 2057 patients (12.4%), whereas the non-CKD group included 14,534 individuals (87.6%). In the CKD cohort, 43.5% had early-stage CKD and 56.5% had advanced-stage CKD. After excluding unmatched participants using PSM, 5173 polyps in 1713 participants were analysed, and the IPTW analysis included 119,804 polyps in 46,486 patients.

3.3 | Association Between CKD and DPPB

Both PSM and IPTW analyses demonstrated that patients with CKD exhibited a higher OR for DPPB than non-CKD individuals (PSM, OR 1.80, CI 1.12–2.89, $p = 0.01$; IPTW, OR 1.98, CI 1.72–2.28, $p < 0.01$) (Figure 2). Notably, early-stage CKD (stages 1 and 2) also presented a significantly elevated risk of DPPB (OR 2.38, 95% CI 1.01–5.64; $p = 0.02$). The OR for DPPB increased progressively with the advancing CKD stage, indicating a higher risk in advanced stages (OR 2.80, 95% CI 1.20–6.51; $p < 0.01$) (Figure 2). The results obtained using IPTW are consistent with those obtained using PSM (OR 1.37, 95% CI 1.16–1.62 for early-stage and OR 1.46, 95% CI 1.23–1.73 for advanced-stage, all $p < 0.05$).

3.4 | Sensitivity Analysis

A sensitivity analysis comparing incidence rates between CKD and non-CKD groups was conducted by categorizing CKD into five stages. The results of this analysis were consistent with the main findings, confirming a higher risk of DPPB across all CKD stages compared with non-CKD patients (Figure S2). Additionally, a separate sensitivity analysis stratified by polyp size (< 10 mm, 10–20 mm, 20–30 mm, and more than 30 mm) demonstrated that larger polyps were progressively associated with a higher risk of DPPB in both the CKD and non-CKD cohorts (Figure S3).

Over the past decade, the adoption of CSP, linked to lower DPPB risk, has increased globally. We conducted additional analyses at 10-year intervals (2005–2013, 2014–2022) to account for these changes, as detailed in Figure S4. These interval-based sensitivity analyses yielded findings that were relatively aligned with the main results of our study.

4 | Discussion

This large cohort study investigated the association between CKD and the risk of colonoscopic DPPB. The main findings are: (1) Compared with the non-CKD group, individuals with CKD had a 1.80-fold increased risk of DPPB. (2) Even early-stage CKD was associated with a 2.38-fold increase in DPPB risk compared with non-CKD individuals. (3) The risk of DPPB significantly correlated with CKD severity, showing a trend of increasing risk with more advanced CKD stages (early-stage CKD, OR 2.38; advanced-stage CKD, OR 2.80). (4) The results remained consistently robust when analysed using IPTW.

Several studies have reported an increased risk of colorectal neoplasia, including CRC and colorectal adenoma, in patients with CKD or ESRD [17–19]. The incidence of CRC or colorectal adenoma is approximately twice as high in the CKD population than in the general population [17, 18]. Therefore, early identification and treatment of precancerous and early cancer lesions through colonoscopic polypectomy are crucial in these patients to prevent progression to invasive CRC. However, concerns about the safety of colonoscopic polypectomy in patients with CKD are increasing [21–25]. Previous studies have indicated that CKD or ESRD is associated with an

TABLE 2 | Logistic regression of risk factors for DPPB.

Variables	Univariate			Multivariate (adjusted)		
	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Patient-related factor						
Demographic variables						
Age, years	1.03	1.02–1.04	< 0.01	1.01	0.99–1.02	0.34
Male	1.31	1.02–1.69	0.03	1.10	0.84–1.44	0.48
Body mass index, kg/m^2	0.96	0.92–0.99	0.03	0.96	0.92–1.00	0.05
Comorbidities						
Hypertension	1.87	1.45–2.40	< 0.01	1.22	0.91–1.65	0.19
Diabetes mellitus	2.34	1.81–3.02	< 0.01	1.49	1.11–2.00	0.01
Liver cirrhosis and chronic liver disease	0.81	0.44–1.51	0.51			
Cardiovascular and cerebrovascular disease	1.81	1.27–2.59	< 0.01	1.13	0.76–1.69	0.54
Chronic kidney disease	2.51	1.91–3.30	< 0.01	1.44	1.05–1.98	0.03
Cancers	1.30	0.97–1.74	0.08			
Medication						
Antiplatelets	1.93	1.23–3.01	< 0.01	1.31	0.81–2.12	0.27
Anticoagulants	3.26	1.86–5.72	< 0.01	2.32	1.23–4.38	0.01
NSAIDs and corticosteroids	0.93	0.61–1.43	0.75			
Laboratory findings						
Haemoglobin, g/dL	0.87	0.82–0.92	< 0.01	0.95	0.89–1.01	0.11
Platelet count, $10^9/L$	1.00	0.99–1.00	0.94			
Prothrombin time, INR	1.50	1.03–2.19	0.03	1.00	0.60–1.65	0.99
aPTT, sec	1.01	1.00–1.03	0.06			
Polyp-related factors						
Polyp number per patient	1.16	1.13–1.20	< 0.01	1.05[a]	1.02–1.09	0.01
Polyp size (mm)	1.12	1.11–1.14	< 0.01			
Polyp size						
< 10 mm		(Reference)			(Reference)	
10–20 mm	5.25	4.01–6.88	0.33	3.35	2.44–4.62	0.09
20–30 mm	14.48	9.60–21.82	< 0.001	8.45	5.33–13.41	< 0.01
> 30 mm	16.34	8.46–31.58	< 0.001	11.05	5.57–21.93	< 0.01
Morphology						
Non-pedunculated		(Reference)			(Reference)	
Pedunculated	2.11	1.66–2.70	< 0.01	1.35	1.04–1.75	0.02
Location						
Right colon		(Reference)				
Left colon	1.03	0.80–1.33	0.45			
Rectum	0.85	0.56–1.30	0.40			
Histopathologic results						
Non-adenomatous		(Reference)				
Adenomatous	1.26	0.91–1.75	0.16			

(Continues)

TABLE 2 | (Continued)

Variables	Univariate			Multivariate (adjusted)		
	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Procedure-related factors						
Resection method						
Cold (CFP, CSP)		(Reference)			(Reference)	
Hot (EMR, ESD)	2.79	2.20–3.54	< 0.01	1.26	0.95–1.67	0.11
Procedure time, min	1.02	1.01–1.02	< 0.01	1.01	1.00–1.01	0.04
Endoscopist experience						
Trainee		(Reference)				
Experienced	0.91	0.71–1.16	0.43			
Bowel preparation						
Excellent + good		(Reference)				
Adequate + poor	1.20	0.88–1.63	0.25			
Preventive haemostasis	2.50	1.86–3.38	< 0.01	0.92	0.64–1.32	0.65
Immediate post-polypectomy bleeding	2.54	1.76–3.65	< 0.01	1.10	0.72–1.66	0.66

Abbreviations: aPTT, activated partial thromboplastin time; CFP, cold forceps polypectomy; CSP, cold snare polypectomy; DPPB, delayed post-polypectomy bleeding; EMR, endoscopic mucosal resection; ESD, endoscopic submucosal dissection; INR, international normalized ratio; NSAID, nonsteroidal anti-inflammatory drug; OR, odd ratio.
[a]For each increase in the number of polyps, the risk of DPPB increases by 5%.

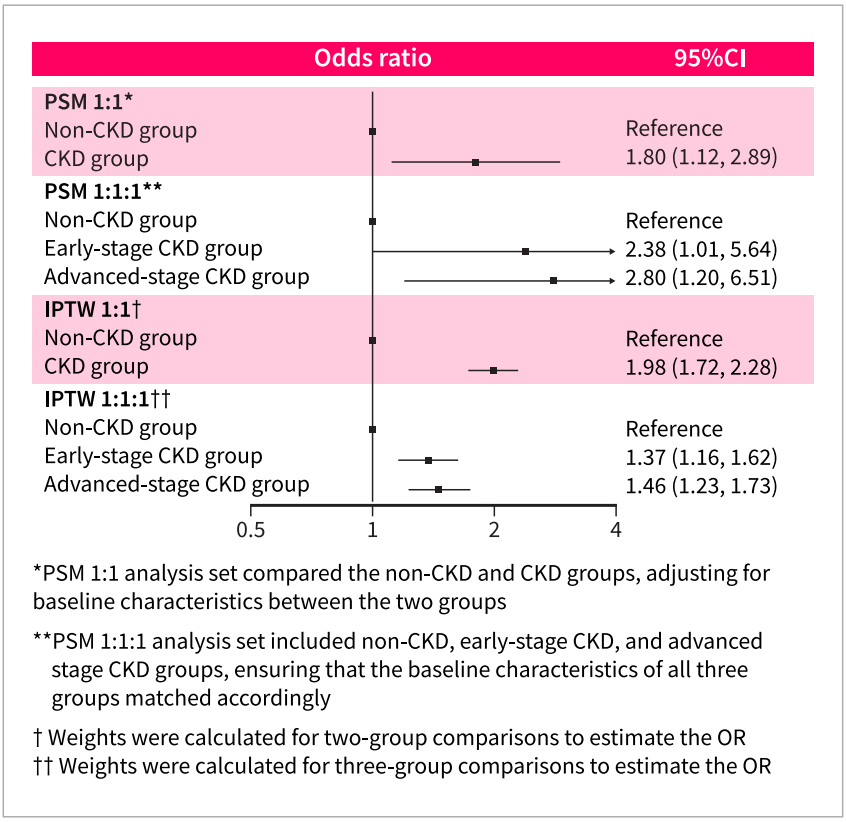

FIGURE 2 | Forest plot of the risk of DPPB in patients with chronic kidney disease (PSM and IPTW). Both PSM and IPTW analyses showed that patients with CKD had a significantly higher risk of DPPB than non-CKD individuals (OR 1.80, CI 1.12–2.89, $p = 0.01$; OR 1.98, CI 1.72–2.28, $p < 0.01$).

approximately twofold higher risk of colonoscopic PPB or perforation [24, 25]. Another prospective, cross-sectional, multicenter study of 5152 patients who underwent polypectomy identified nine risk factors positively associated with the incidence of IPPB, including CKD as one of the analysed variables [23]. However, these studies had notable shortcomings, such as focussing only on patients with ESRD and not those with CKD and failing to utilise a variety of statistical analyses,

limiting the strength of their conclusions [21, 25, 26]. Additionally, most studies did not fully adjust for confounding factors such as the use of antiplatelets or anticoagulants, the characteristics of polyps (including their shape, location, and numbers), laboratory findings, histopathological results, or details related to endoscopic procedures [21, 23–28]. Given the heterogeneity of the CKD population compared to the general population, it is challenging to determine the safety of colonoscopic polypectomy in CKD from previous studies [46, 47]. Therefore, to address these limitations, we conducted a comprehensive study with a substantial sample size ($n = 41{,}014$), meticulously adjusting for all potential risk factors using PSM and IPTW to provide robust evidence.

Our study comprehensively addressed the patient-, polyp-, and endoscopic procedure-related factors. We examined the relationship between CKD severity and DPPB following colonoscopic polypectomy by employing robust analytical methods such as PSM and IPTW. Through these rigorous analyses, we demonstrated that the risk of DPPB significantly increases not only in advanced-stage CKD but also in early-stage CKD. These findings provide clear evidence that strategies to prevent bleeding should be implemented during colonoscopy and polypectomy in all patients with CKD. Close inspection and irrigation of the resection site to monitor for IPPB may be beneficial to minimize the risk of complications in patients with CKD [48, 49]. Moreover, using diathermy-free techniques (CSP, cold EMR) rather than diathermy-based techniques (traditional EMR) can help minimize bleeding risks [50]. Although ESGE guidelines do not recommend routine clip closure [35], it can be considered for high-risk patients, such as those with CKD and large polyps (> 10 mm). In such cases, the proactive use of prophylactic endoscopic techniques may be advantageous.

DPPB is an infrequent occurrence with a very low associated mortality rate [51]. However, its impact should not be underestimated as its occurrence often necessitates repeat endoscopic procedures, a significant number of hospitalizations and increased healthcare costs ultimately causing patient discomfort and reduced quality of life (QOL) [52]. According to our study, patients with CKD exhibit a significantly higher incidence of DPPB compared with the general population, which adversely affects healthcare costs, patient safety, and overall QOL. Recognizing the heightened risk of DPPB in CKD patients and implementing strategies to mitigate this risk are of critical clinical importance. Furthermore, providing patients with adequate attention and detailed explanations about their condition and the measures being taken to reduce DPPB risk is essential for optimal care and safety.

The mechanisms underlying the increased bleeding risk in patients with CKD are poorly understood and vary between early-stage and advanced-stage CKD, necessitating further research [27, 28]. In early-stage CKD, although the decrease in eGFR is not severe, the presence of albuminuria indicates endothelial cell dysfunction in the glomerular basement membrane as well as systemic endothelial cell dysfunction. This dysfunction can lead to an impaired balance between prothrombotic and antithrombotic factors, compromising the integrity of the vascular endothelium and thereby increasing the susceptibility to bleeding. In advanced-stage CKD, the risk of bleeding is likely to be elevated due to more severe systemic endothelial cell dysfunction, in addition to other factors such as uraemic platelet dysfunction, in which the accumulation of uraemic toxins impairs platelet function and reduces their ability to aggregate properly and form effective clots, significantly elevating the risk of bleeding. Furthermore, patients with advanced CKD frequently suffer from anaemia due to erythropoietin deficiency, which exacerbates bleeding tendencies by reducing the number of red blood cells available to support platelet plug formation. Although these factors are believed to contribute to increased bleeding risk in CKD, additional research is necessary to fully understand these mechanisms.

Previous studies have reported that various patient- or polyp-related factors (e.g., advanced age, diabetes, liver disease, anti-thrombotic use, polyp size, and resection method) can influence the risk of DPPB [23, 26, 53]. While the results for many of these factors remain inconsistent [25, 40, 54], the polyp size and resection method have shown a relatively consistent association with PPB in the literature [35, 36]. In our study, polyp size demonstrated a significant association with DPPB in both univariate and multivariate analyses, including within the CKD cohort. However, the resection method did not show a significant relationship with DPPB in our dataset. Typically, polyp size plays a critical role in determining the resection method (cold vs. hot) [35, 36]. Consistent with this, our data revealed a statistically significant association between polyp size and resection method (Cochran-Armitage Trend Test, $p < 0.0001$). In the multivariate analysis (Table 2), polyp size remained significant, while the resection method did not, likely due to the strong correlation between these two factors.

This study has several strengths. First, we used a large clinical cohort, enabling large-scale PSM with 27 covariates, a feature lacking in previous studies. Meticulous matching of potential confounders may influence the risk of PPB, including sociodemographic factors, comorbidities, medication use, laboratory findings, and several polyp- or procedure-related factors that mitigate confounding. Second, considering the significant heterogeneity of the patients with CKD compared with the general population, we simultaneously performed both PSM and IPTW to reduce heterogeneity and achieve a balance between the groups. Both PSM and IPTW yielded highly consistent results. These methodological strengths ensured robust and reliable results, highlighting the intricate relationship between CKD and the risk of DPPB. Furthermore, multigroup PSM for head-to-head comparisons in multiple cohorts provided strong evidence through a sensitivity analysis, confirming the results under perfect control. Simultaneously presenting IPTW results with weights accounted for using the entire pooled population reinforced the robustness of our findings.

This study has some limitations. First, despite including various covariates, this study may not have eliminated the impact of residual confounders from inadequately measured or missing factors. For instance, our dataset lacked information on CKD duration, the Charlson Comorbidity Index, indication of colonoscopy, and exact timing of anti-thrombotic resumption, all of which may impact DPPB risk. Second, the selection of representative polyps from patients with multiple

polyps could be a confounding variable and may have resulted in a selection bias. However, representative polyps were selected not randomly but by considering factors associated with bleeding risk and by differentially prioritising size, resection method, and polyp morphology [36, 55]. Third, our retrospective cohort study could not establish a causal relationship between CKD and DPPB. Although this study was conducted on a large scale, with considerable efforts to control for bias, the findings suggest only a potential association between CKD and DPPB. Fourth, PSM analysis was conducted by grouping CKD into early and advanced stages due to insufficient sample sizes for robust interpretation. Nonetheless, sensitivity analysis categorizing CKD into five stages showed consistently high DPPB risks across all stages, consistent with the main findings. Fifth, patients undergoing renal replacement therapy (defined as those on dialysis or with a history of kidney transplantation) were excluded from our study as these individuals may have a different risk profile for DPPB compared to those with CKD. This exclusion could introduce selection bias. Finally, as the study was conducted at only two centres and primarily involved the Korean population, caution should be exercised when applying and interpreting these results to other ethnic groups or countries. Therefore, larger, multicenter studies, including patients receiving renal replacement therapy, are required to validate our findings and provide stronger evidence on the relationship between CKD and DPPB risk.

In conclusion, CKD, including early-stage CKD, is closely associated with DPPB, and this association becomes stronger as CKD progresses. Therefore, careful monitoring of bleeding is necessary for at least 1 month after colonoscopic polypectomy across all CKD stages.

Author Contributions

Conception and design: Hye Kyung Hyun, Hae-Ryong Yun, and Cheal Wung Huh. Development of methodology: Hye Kyung Hyun, Nak-Hoon Son, Hae-Ryong Yun, and Cheal Wung Huh. Acquisition, analysis, and interpretation of data: Hye Kyung Hyun, Nak-Hoon Son, Hyun Chul Lim, Jihye Park, Soo Jung Park, Jae Jun Park, Jae Hee Cheon, Tae Il Kim, Tae-Hyun Yoo, Shin-Wook Kang, Hae-Ryong Yun, and Cheal Wung Huh. Writing, review, and/or revision of the manuscript: Hye Kyung Hyun, Nak-Hoon Son, Hae-Ryong Yun, and Cheal Wung Huh. Administrative, technical, or material support: Hye Kyung Hyun, Nak-Hoon Son, Hae-Ryong Yun, and Cheal Wung Huh. Study supervision: Hae-Ryong Yun and Cheal Wung Huh.

Ethics Statement

This study was performed in accordance with the ethical guidelines of the 1975 Declaration of Helsinki and was approved by the Institutional Review Board of Yongin Severance Hospital (IRB No. 9-2022-0116; date of registration, October 21, 2022).

Consent

Informed consent was not required owing to the retrospective study design.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data underlying this article will be shared on reasonable request to the corresponding author.

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Supporting Information

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