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# Does international normalized ratio level predict pulmonary embolism?

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Running title: **INR Level and PE?**

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Each author certifies that his/her institution has approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research

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1 **Abstract** (Word count: 249 words)

2 *Background* Preventing PE is a priority after major musculoskeletal surgery. There is  
3 discrepancy in published data regarding the influence that anticoagulation has on the  
4 incidence of PE following joint arthroplasty. The American College of Chest Physicians  
5 guidelines recommend administration of oral anticoagulants (warfarin), aiming for an  
6 INR level between two and three. However, recent studies show aggressive  
7 anticoagulation (INR greater than two) can lead to hematoma formation and increased  
8 risk of subsequent infection.

9 *Questions/purposes* We asked whether an INR greater than two is protective against PE.

10 *Patients and Methods* We identified 9,112 patients with 10,122 admissions for joint  
11 arthroplasty between 2004 and 2008. All patients received warfarin for prophylaxis,  
12 aiming for an INR level of two or below. Of the 10, 122 admissions, we assessed 609  
13 (6%; 609/10122) for PE using CT, VQ scan, or pulmonary angiography. Of these, 163  
14 patients (1.6%; 163/10122) had a proven PE.

15 *Results* Of these 163 patients, 9% (15/163) had an INR greater than two prior to or on the  
16 day of work-up compared to 8% (35/446) of patients who were negative. We observed  
17 no difference between the INR values in patients with or without PE.

18 *Conclusions* We found no clinically relevant difference in the INR values of patients who  
19 did or did not develop PE. The risk of bleeding should be weighed against the risk of PE  
20 when determining an appropriate target INR for each patient, as an INR less than two  
21 may reduce the risk of bleeding while still protecting against PE.

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- 22 **Level of Evidence:** Level III Therapeutic study. See Instructions to Authors for a  
23 complete description of levels of evidence.

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## 24 **Introduction**

25 Pulmonary embolism (PE) is a serious and potentially fatal complication that can develop  
26 following total joint arthroplasty (TJA), with an incidence of 1.1 to 1.82% after total knee  
27 arthroplasty (TKA) and 0.51 to 0.9% after total hip arthroplasty (THA) [12,18,19].

28 Patients undergoing TJA are considered to be at higher risk for PE. Prevention of PE  
29 following orthopaedic procedures continues to be a priority. For this reason, various  
30 scientific groups have devised guidelines for implementation of anticoagulation  
31 prophylaxis to minimize this complication [10,11].

32 In 2008 the American College of Chest Physicians (ACCP) issued updated guidelines  
33 regarding postoperative PE prophylaxis in elective hip or knee arthroplasty [10]. These  
34 guidelines endorse the use of low molecular weight heparin (LMWH), fondaparinux, or  
35 Vitamin-K antagonists to achieve an international normalized ratio (INR) between two  
36 and three. These guidelines, however, make the assumption that deep venous thrombosis  
37 (DVT) and PE should be treated as the same entity and that the former is likely to lead to  
38 the latter. A recently published study discredited this relationship [16]. Further, the  
39 ACCP guidelines do not account for the risk or severity of bleeding complications  
40 associated with anticoagulation. At an INR of two to three, the incidence of major  
41 bleeding complications ranges from 5.0% to 5.6% after TKA and 0.6% to 1.6% after  
42 THA [8,9,17]. In those same studies, the rate of minor bleeding complications following  
43 TKA and THA reportedly ranges from 21% to 28% and 4.6% to 13.5%, respectively.

44 With the increased risk of bleeding complications, it is important to understand the  
45 effectiveness of therapeutic anticoagulation in minimizing PE. We previously  
46 demonstrated the low risk of complications with the use of low-dose warfarin (i.e. aiming

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47 for an INR less than two) for preventing PE [1]. That study was the basis for  
48 implementing the use of low-dose warfarin (aiming for an INR less than two) in patients  
49 undergoing TJA in 1990.

50 We therefore asked whether an INR level greater than two, as dictated by the ACCP  
51 guidelines, following TJA is protective against PE.

## 52 **Patients and Materials**

53 From our institutional database we retrospectively identified 9,112 patients who  
54 underwent TJA between January 2004 and June 2008 and had at least a single  
55 postoperative INR value available. Those patients who underwent work-up for PE yet  
56 did not have an INR value on the day of or prior to scan were excluded. During that  
57 same time, we treated 9,973 patients with TJA. Therefore, 861 patients were excluded  
58 due to lack of complete data, the demographics of these two groups were investigated  
59 (Table 1). The 9,112 patients had an average age of 64 years (range, 11-103 years) and  
60 had 10,122 admissions for 11,300 procedures (4,727 primary hips, 5,079 primary knees,  
61 803 revision hips, 615 revision knees, and 76 hemiarthroplasties). Patients were followed  
62 until discharge from the hospital, on average 6.3 days (range: 2-56 days). Any patients  
63 with symptoms indicative of PE were investigated. Since this study observational  
64 window ended at discharge, no patients were lost to followup. No patients were recalled  
65 specifically for this study; all data was obtained from medical records.

66 The protocol for anticoagulation at our institution throughout the study period consisted  
67 of administration of 1000 IU of intravenous heparin at the time of dislocation of the hip  
68 during hip arthroplasty and prior to inflation of the tourniquet during knee arthroplasty.

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69 In addition, we placed patients on oral anticoagulation (warfarin), aiming for an INR  
70 level of two or below. Patients continued on the anticoagulation for a period of six weeks.  
71 The institutional guidelines are modeled after the recommendations from the AAOS [11]  
72 for prevention of PE after TJA. These guidelines were developed without regard for the  
73 prevention of DVT. This conflicts with the recommendations made by the ACCP [10],  
74 whose means of PE prevention include prophylaxis against DVT. There were variations  
75 based on the risk profile of patients for PE and bleeding. We gave patients at higher risk  
76 of PE low molecular weight heparin in addition to oral anticoagulation until their INR  
77 level reached therapeutic levels. We considered patients at high risk for PE as those with  
78 previous PE, polycythemia vera, and those in a hypercoagulable state. On the other hand,  
79 we gave patients at high risk of bleeding aspirin for anticoagulation. We considered  
80 patients at high risk for bleeding as those with recent cranio-spinal surgery, active gastric  
81 ulcer, and hemophilia. Prophylaxis with warfarin involved administration of the drug on  
82 the operative day. We monitored the INR daily while the patient was in the hospital, and  
83 dosed warfarin according to their INR level. The mean preoperative INR for the entire  
84 cohort of 10,122 admissions was 1.09. The median daily postoperative values for INR  
85 were 1.13 (range, 0.67-3.04) on postoperative day (POD) zero, 1.24 (range, 0.6-5.8) on  
86 POD one, 1.39 (range, 0.4-7.0) on POD two, 1.32 (range, 0.7-5.3) on POD three, 1.33  
87 (range, 0.9-5.2) on POD four, and 1.41 (range, 0.8-4.3) on POD five (Fig. 1). The  
88 proportion of patients with an INR greater than two was 0.7 %, 0.2%, 6.4%, 3.1%, 4.5%,  
89 and 8.6% for the POD zero through five, respectively (Fig. 2). We plotted the percentage  
90 of patients who had an INR greater than two in the PE positive and PE negative groups  
91 against the day of scan, including the five days before and after the scan. The work-up

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92 for PE at our institution followed a standard protocol as well. This protocol underwent  
93 some modification over time. In general, we first administered oxygen to patients with  
94 hypoxia and monitored them very closely (Appendix). If within five to ten minutes of  
95 oxygen therapy hypoxia was not resolved, we imaged these patients for PE, which  
96 included multi-detector computed tomography (MDCT), VQ scan and, in rare cases,  
97 pulmonary angiography. We evaluated patients with other signs suggestive of PE, such  
98 as tachycardia, tachypnea, dyspnea, and so on, thoroughly and, based on the judgment of  
99 the evaluating internist, subjected them for PE work-up.

100 From among the 10,122 admissions, 600 patients (609 admissions; 6.0 %) were scanned  
101 for PE. This subset had an average age of 69 years (range, 24-96 years) and consisted of  
102 424 (73.5%) women. These patients had 710 arthroplasty procedures (194 primary hips,  
103 428 primary knees, 38 revision hip, 42 revision knee, and eight hemiarthroplasties) in 621  
104 admissions. Following work-up for PE, 163 admissions (163/10,122; 1.6%) were  
105 positive for PE and included in the positive PE subgroup. Among the 609 admissions  
106 that received work-up for PE, the majority (41.2%; 251/609) were scanned on POD 2  
107 (Fig. 1). We assessed their daily INR values to identify any variations in their INR  
108 relative to the remaining patients who were negative for PE and the entire arthroplasty  
109 cohort. We utilized the Charlson comorbidity index [3], as modified by Deyo et al. [5],  
110 to assess comorbidities. This index is adjusted for age. Variables describing differences  
111 between PE positive and PE negative patients are reported (Table 2). Furthermore, the  
112 same variables are reported for patients with a post-operative INR greater than two versus  
113 INR less than two (Table 3).

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114 To analyze the anticoagulation (INR) levels and confounding variables of the three  
115 cohorts we utilized a series of statistical tests. First, the data was tested for normality  
116 using the Kolmogorov-Smirnov test. Normal continuous data was assessed using the  
117 Student's t-test, and confidence intervals provided clinical significance of variations.  
118 Non-normal continuous data was assessed with the Mann-Whitney test, and twenty-fifth  
119 and seventy-fifth percentiles were used to represent the variation of data. Chi-squared  
120 analysis was used for categorical data. All data analysis was done using SPSS 16.0  
121 (Chicago, IL).

## 122 **Results**

123 Female gender ( $p = 0.04$ ), body mass index ( $p < 0.001$ ), knee replacement ( $p < 0.001$ ),  
124 increasing age ( $p < 0.001$ ), and an increase in age-adjusted Charlson Index ( $p < 0.0001$ )  
125 were risk factors for developing PE (Table 2). Type of arthroplasty (revision versus  
126 primary) did not predict development of PE. There were no differences between the  
127 confirmed PE positive and confirmed PE negative groups with regards to proportion of  
128 patients with an INR greater than two on the day of or prior to the work-up (9.2% in PE  
129 positive versus 7.9% in PE negative;  $p = 0.55$ ). On the first day after the scan, the PE  
130 negative group tended to have a higher percentage of patients ( $p = 0.11$ ) with an INR  
131 greater than two. On post-scan days three, four, and five, there was a higher percentage  
132 ( $p = 0.009$ ,  $0.0001$ , and  $0.0002$ , respectively) of PE positive patients with an INR greater  
133 than two (Fig.3). Patients with confirmed PE had higher INR on POD five ( $p = 0.02$ )  
134 compared to confirmed PE negative. When aggregating confirmed PE negative patients  
135 with patients that were not worked-up, PE positive patients had a higher INR on POD  
136 two, three, four, and five ( $p = 0.012$ ,  $p = 0.001$ ,  $p < 0.001$ , and  $p < 0.001$ , respectively).

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137 **Discussion**

138 Pulmonary embolism is a dreaded and life-threatening complication that can develop  
139 after TJA, with an incidence of 1.1 to 1.82% following TKA and 0.51 to 0.9% after THA  
140 [12,18,19]. The 2008 updated ACCP guidelines regarding postoperative PE prophylaxis  
141 in musculoskeletal patients [10], endorsed the use of LMWH, fondaparinux, or Vitamin-  
142 K antagonists to achieve an INR between two and three. These guidelines, however,  
143 assume that DVT is a proxy for PE. Even more, the ACCP guidelines do not consider the  
144 risk of severe bleeding associated with anticoagulation, which ranges from 5.0% to 5.6%  
145 following TKA and 0.6% to 1.6% after THA [8,9,17], as well as the risk for minor  
146 bleeding complications following TKA and THA (21% to 28% and 4.6% to 13.5%,  
147 respectively). Safety and low risk of complications with the use of low-dose warfarin  
148 (i.e. aiming for an INR less than two) for preventing PE has been demonstrated [1]. We  
149 therefore asked whether an INR level greater than two, as dictated by the ACCP  
150 guidelines, following TJA is protective against PE.

151 This study is limited by a number of issues. First, while the relatively large size of  
152 patients undergoing evaluation for PE adds to its strength, some patients in this study  
153 may have received work-up for PE following discharge from the hospital that were not  
154 disclosed to their treating surgeon. Second, due to the fact that our observational window  
155 was focused on in-hospital data only; incidence of PE may be skewed, and PE occurring  
156 up to three or more months post-operatively were not captured. Third, due to the  
157 retrospective nature of the study, it is not possible to provide an accurate number  
158 (although small) of those patients that deviated from the main anticoagulation protocol  
159 (i.e. patients with previous PE, polycythemia vera, and those in a hypercoagulable state)

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160 who received an alternate anticoagulation protocol. Fourth, there are no set standards in  
161 defining PE and it is plausible that some of the emboli seen on lung scans (MDCT) were  
162 fat emboli that could not be distinguished from venous emboli. Fifth, not all patients in  
163 this study had pulmonary angiography, which is considered the gold standard for  
164 diagnosis of PE. Due to the invasive nature of the test and the costs involved, pulmonary  
165 angiography is reserved for only a limited number of patients. Furthermore, not all  
166 patients included in this analysis underwent work-up for PE. This led us to separate the  
167 cohort into three groups (PE positive, PE negative and not scanned). While we make the  
168 assumption that asymptomatic patients were PE negative, this cannot be truly confirmed  
169 without invasive work-up. Sixth, this study is only evaluating the efficacy of an INR  
170 target (less than two) set at our institution. These results do not exclude the possibility  
171 that a lower INR target would be as efficacious at preventing PE.

172 This study highlights some important findings. First, the incidence of PE is low (1.6%)  
173 and comparable to literature [14,19] using low-dose warfarin, with no fatal PE during the  
174 period of this study. Second, there is no correlation between the level of INR and the  
175 development of PE. It appears that PE could develop in any patient, including those with  
176 an INR greater than two. These findings raise the possibility that either INR fails to  
177 measure the efficacy of warfarin as an anticoagulant or that prophylactic anticoagulation  
178 has no effect on the incidence of PE. A study, (130,000 patients), demonstrated that the  
179 incidence of PE among patients without anticoagulation prophylaxis (0.12%) is the same  
180 as those receiving it (0.095%) [13]. Although, there is a division among the orthopaedic  
181 surgeons regarding the most effective modality, they agree that some form of VTE  
182 prophylaxis is warranted. Some believe that improvements in surgical and anesthesia

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183 care for patients undergoing TJA have made administration of chemical anticoagulation  
184 unnecessary [2].

185 Orthopaedic surgeons consistently take an active role in preventing PE; however, there  
186 are key differences between the manner that they and medical physicians approach this  
187 complication. First, they observe that 8.9% to 25.6% of TJA patients develop DVT,  
188 while only 0.5% to 2.0% developed PE [14,19]. For this reason, the American  
189 Association of Orthopaedic Surgeons (AAOS) recommends treating DVT and PE as  
190 separate entities. Second, they are committed to minimizing bleeding complications in  
191 their surgical patients; these can be as devastating to patients as PE [15]. A study  
192 comparing low-dose warfarin with a target INR of 1.5 to two with a historical control  
193 group with a target INR of two to three, found no difference in the incidence of DVT, PE,  
194 or death [4,7]. Expectedly though, a higher incidence of bleeding complications occurs  
195 in the higher target INR group. Major bleeding complications can be a foundation for  
196 infection, wound healing problems, functional disability, and prosthetic loosening [7].  
197 All of these consequences can lead to reoperation and increase in morbidity and  
198 mortality. Third, pneumatic compression boots and aspirin, along with regional  
199 anesthesia, are suggested as being non-inferior to chemoprophylactic anticoagulants at  
200 preventing PE without the increased bleeding complications [6]. Interestingly, potent  
201 anticoagulants like warfarin and LMWH are associated with increased all-cause mortality  
202 rates, including PE, when compared to pneumatic compression boots and aspirin [20]. It  
203 is from this point of view that the AAOS created the guidelines stating that patients at a  
204 standard risk of both PE and bleeding can be given aspirin, LMWH, synthetic  
205 pentasaccharides, or warfarin to reach an INR goal of less than or equal to two [11]. A

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206 previous prospective study from this institution that involved performing preoperative  
207 and postoperative VQ scans in a consecutive series of patients undergoing TJA found that  
208 low dose warfarin (with an INR goal of less than two) is effective at minimizing  
209 development of PE, with a low (2.4%) bleeding complication [1]. Based on these  
210 findings, we have used low-dose warfarin as a prophylaxis for prevention of PE in our  
211 patients over the last two decades.

212 The most pertinent finding of this study is that an INR greater than two does not appear  
213 to protect against PE. Thus, implementing the recommendations of ACCP [10] in aiming  
214 for an INR greater than two may not protect these patients against PE, while exposing  
215 them to the undue risk of bleeding and all untoward consequences that may ensue [8,9].  
216 Despite the limitations, we believe our data and that in the literature casts doubt on the  
217 belief that administration of aggressive anticoagulation can and does protect patients  
218 against development of PE.

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**Acknowledgements:**

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## Reference List

1. Balderston RA, Graham TS, Booth RE, Jr., Rothman RH. The prevention of pulmonary embolism in total hip arthroplasty. Evaluation of low-dose warfarin therapy. *J Arthroplasty*. 1989;4:217-221.
2. Callaghan JJ, Dorr LD, Engh GA, Hanssen AD, Healy WL, Lachiewicz PF, Lonner JH, Lotke PA, Ranawat CS, Ritter MA, Salvati EA, Sculco TP, Thornhill TS. Prophylaxis for thromboembolic disease: recommendations from the American College of Chest Physicians--are they appropriate for orthopaedic surgery? *J Arthroplasty*. 2005;20:273-274.
3. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40:373-383.
4. Clark NP, Witt DM, Delate T, Trapp M, Garcia D, Ageno W, Hylek EM, Crowther MA. Thromboembolic consequences of subtherapeutic anticoagulation in patients stabilized on warfarin therapy: the low INR study. *Pharmacotherapy*. 2008;28:960-967.
5. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. *J Clin Epidemiol*. 1992;45:613-619.
6. Dorr LD, Gendelman V, Maheshwari AV, Boutary M, Wan Z, Long WT. Multimodal thromboprophylaxis for total hip and knee arthroplasty based on risk assessment. *J Bone Joint Surg Am*. 2007;89:2648-2657.
7. Enyart JJ, Jones RJ. Low-dose warfarin for prevention of symptomatic thromboembolism after orthopedic surgery. *Ann Pharmacother*. 2005;39:1002-1007.
8. Fitzgerald RH, Jr., Spiro TE, Trowbridge AA, Gardiner GA, Jr., Whitsett TL, O'Connell MB, Ohar JA, Young TR. Prevention of venous thromboembolic disease following primary total knee arthroplasty. A randomized, multicenter, open-label, parallel-group comparison of enoxaparin and warfarin. *J Bone Joint Surg Am*. 2001;83-A:900-906.
9. Freedman KB, Brookenthal KR, Fitzgerald RH, Jr., Williams S, Lonner JH. A meta-analysis of thromboembolic prophylaxis following elective total hip arthroplasty. *J Bone Joint Surg Am*. 2000;82-A:929-938.
10. Geerts WH, Bergqvist D, Pineo GF, Heit JA, Samama CM, Lassen MR, Colwell CW. Prevention of venous thromboembolism: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines (8th Edition). *Chest*. 2008;133:381S-453S.

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11. Johanson NA, Lachiewicz PF, Lieberman JR, Lotke PA, Parvizi J, Pellegrini V, Stringer TA, Tornetta P, III, Haralson RH, III, Watters WC, III. American academy of orthopaedic surgeons clinical practice guideline on. Prevention of symptomatic pulmonary embolism in patients undergoing total hip or knee arthroplasty. *J Bone Joint Surg Am.* 2009;91:1756-1757.
12. Mantilla CB, Horlocker TT, Schroeder DR, Berry DJ, Brown DL. Frequency of myocardial infarction, pulmonary embolism, deep venous thrombosis, and death following primary hip or knee arthroplasty. *Anesthesiology.* 2002;96:1140-1146.
13. Murray DW, Britton AR, Bulstrode CJ. Thromboprophylaxis and death after total hip replacement. *J Bone Joint Surg Br.* 1996;78:863-870.
14. O'Reilly RF, Burgess IA, Zicat B. The prevalence of venous thromboembolism after hip and knee replacement surgery. *Med J Aust.* 2005;182:154-159.
15. Parvizi J, Azzam K, Rothman RH. Deep venous thrombosis prophylaxis for total joint arthroplasty: American Academy of Orthopaedic Surgeons guidelines. *J Arthroplasty.* 2008;23:2-5.
16. Parvizi J, Jacovides CL, Bican O, Purtill JJ, Sharkey PF, Hozack WJ, Rothman RH. Is deep vein thrombosis a good proxy for pulmonary embolus? *J Arthroplasty.* 2010;25:138-144.
17. Pellegrini VD, Jr., Sharrock NE, Paiement GD, Morris R, Warwick DJ. Venous thromboembolic disease after total hip and knee arthroplasty: current perspectives in a regulated environment. *Instr Course Lect.* 2008;57:637-661.
18. Phillips CB, Barrett JA, Losina E, Mahomed NN, Lingard EA, Guadagnoli E, Baron JA, Harris WH, Poss R, Katz JN. Incidence rates of dislocation, pulmonary embolism, and deep infection during the first six months after elective total hip replacement. *J Bone Joint Surg Am.* 2003;85-A:20-26.
19. Pulido L, Parvizi J, Macgibeny M, Sharkey PF, Purtill JJ, Rothman RH, Hozack WJ. In hospital complications after total joint arthroplasty. *J Arthroplasty.* 2008;23:139-145.
20. Sharrock NE, Gonzalez D, V, Go G, Lyman S, Salvati EA. Potent anticoagulants are associated with a higher all-cause mortality rate after hip and knee arthroplasty. *Clin Orthop Relat Res.* 2008;466:714-721.

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## Legends

**Fig. 1** Graph shows median INR versus day of surgery (columns, left axis) and histogram displaying PE work-up day of scan relative to POD (area curve; right axis). POD two was the maximum day of scans for both positive and negative PE patients.

**Fig. 2** Graph shows percentage of patients with INR greater than two from preoperative to POD five.

**Fig. 3** Graph shows percentage of patients with INR greater than two by day of scan (lines; right axis), as well as median INR related to the day of scan (columns; left axis). Day of scan is 0, the five days before the scan is in reverse chronological order as -1 through -5, and the five days after the scan is days 1 through 5. Displays median values between positive PE and negative PE patients. On the day of scan, there was no difference ( $p = 0.63$ ) between INR values. PE positive patients had higher INR values on post-scan days three, four, and five ( $p = 0.009$ ,  $p < 0.001$ , and  $p < 0.001$ , respectively).

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