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Exposure to postoperative hypothermia and its association with complications after major abdominal surgery: a retrospective cohort study

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Purpose: Many patients who undergo major abdominal surgery experience inadvertent hypothermia during the perioperative period. This study aimed to identify risk factors related to postoperative hypothermia and their association with postoperative complications.
Methods: This retrospective cohort study used data from Seoul National University Bundang Hospital, a tertiary university medical center in South Korea, between January 1, 2018 and December 31, 2022. We included patients aged ≥18 years who underwent elective major abdominal surgery for more than 2 hours in the operating room. The patients were categorized into the hypothermia (body temperature <36.5 °C) and non-hypothermia (body temperature ≥36.5 °C) groups.
Results: The study sample comprised 30,194 patients, and we classified 21,293 and 8,901 into the hypothermic and non-hypothermic groups, respectively. Some factors associated with the occurrence of postoperative hypothermia included the type of surgery. In the multivariable logistic regression model, the incidence of postoperative complications was 9% higher in the hypothermia group than in the non-hypothermic group (odds ratio [OR], 1.09; 95% confidence interval [CI], 1.01–1.19; P = 0.040). Among postoperative complications, the hypothermic group showed a 14% higher incidence of acute kidney injury (OR, 1.14; 95% CI, 1.04–1.25; P = 0.007) than the non-hypothermic group.
Conclusion: The appearance of postoperative hypothermia during the first 30 minutes of the recovery period was significantly associated with the appearance of postoperative complications, especially acute kidney injury. However, further studies are required to validate these findings.
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Key Words: Cohort studies, Hypothermia, Postoperative complications, Surgery

INTRODUCTION

Hypothermia, defined as a core body temperature of <36.5 °C [1], commonly occurs in the perioperative period. Despite normal physiological thermoregulation, up to 70% of patients experience unintentional perioperative hypothermia [2]. This is frequently due to low operating room temperature (typically <23 °C), surgical procedures, and the effects of anesthesia, despite institutional efforts to prevent hypothermia [3].

Perioperative hypothermia can lead to an increased incidence of cardiovascular complications, including stroke, myocardial infarctions [4], and delirium [5], which can increase hospital expenses [6]. However, it also has beneficial effects on specific patients by reducing oxygen demand and decreasing metabolic

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rate. Induced hypothermia can reduce the size of the infarct in patients with anterior infarct [7], as well as the rate of delayed graft function in deceased donor kidney transplantation recipients [8]. Although the association between intraoperative hypothermia and its consequences has been well studied, limited studies exist on immediate postoperative hypothermia and postoperative complications. Therefore, identifying factors associated with postoperative complications and reducing the incidence of postoperative complications are important issues in postoperative management.

This study aimed to identify the association between postoperative hypothermia and complications in patients undergoing major abdominal surgery under general anesthesia. We hypothesized that postoperative hypothermia might have detrimental effects on postoperative complications. The secondary objective was to identify the specific types of postoperative complications related to postoperative hypothermia and to evaluate the risk factors for postoperative hypothermia.

METHODS

Ethical statement

The Institutional Review Board (IRB) of the Seoul National University Bundang Hospital (SNUBH) approved this retrospective cohort study (No. B-2306-832-001; approval date: June 15, 2023). The IRB waived the requirement to obtain informed consent from patients due to the retrospective nature of the study.

Study population

The study included adult patients aged ≥18 years who underwent elective major abdominal surgeries at SNUBH from January 2018 to December 2022. Major abdominal surgeries were defined as any abdominal surgical procedure that lasted for >2 hours in the operating room. Patients with incomplete medical records and those who did not receive general anesthesia were excluded from this study.

Exposure: hypothermia

Body temperatures were measured in SNUBH using an infrared tympanic thermometer (Braun Thermoscan IRT-6030) after the transfer of patients to the postanesthesia care unit (PACU) or intensive care unit (ICU). We collected data on patients' body temperatures at 3 distinct times (on arrival to PACU or ICU and at 15 minutes and 30 minutes postoperatively). Subsequently, we considered the patients as hypothermic if their body temperature dropped below 36.5 °C at least once. Overall, we classified the patients into 3 categories based on their body temperature: normothermia, hypothermia (at least one measurement below 36.5 °C), and hyperthermia (body temperature never dropped below 36.5 °C but exceeded the normothermia range at least once) groups. Further, we broadly classified the patients into 2 groups: hypothermic and non-hypothermic (normothermia and hyperthermia) groups.

Study endpoints

The primary endpoint was a postoperative complication. We analyzed risk factors according to postoperative complications and the presence or absence of hypothermia. These complications included conditions that developed during the postoperative hospitalization. Specifically, acute kidney injury (AKI), urinary tract infection (UTI), pneumonia, delirium, myocardial injury, and stroke were evaluated as postoperative complications.

AKI was diagnosed based on the guidelines of the Kidney Disease: Improving Global Outcomes [9]. Considering the variable duration of urinary catheter placement in patients, we did not monitor urine output but used serum creatinine (mg/dL) alone for diagnosis. Our institution requires that all surgical patients have serum creatinine levels measured within 1 month preoperatively. The value measured on the day closest to the date of surgery was used as a baseline. The UTI was diagnosed based on consultation notes from the Department of Infectious Diseases on the UTI or positive outcomes of genitourinary culture results (leukocytes >100,000 CFU/mL) [10] within 7 days postoperatively. For pneumonia, we interpreted chest radiographs or computed tomography scans within 7 days postoperatively for signs of pneumonia, excluding those with preoperative pneumonia. Delirium was detected using consultation notes from the Department of Neuropsychology or the administration of benzodiazepine/antipsychotic drugs (haloperidol, olanzapine, risperidone, quetiapine, and lorazepam) within 2 days postoperatively. We confirmed that assigned nurses delivered the medications according to the dosages recommended by clinical practice guidelines [11]. For myocardial injury, we reviewed the consultation notes of Department of Cardiology within 1 week postoperatively. Finally, we selected the consultation notes from the Department of Neurology for stroke.

Study parameters and data collection

We retrospectively collected demographic data and characteristics of patients from electronic medical records, including age, sex, American Society of Anesthesiologists classification, serum creatinine level used to evaluate preoperative kidney function [12], and World Health Organization hemoglobin cut-off level for anemia [13]. Comorbidities such as hypertension, diabetes mellitus, heart disease (coronary artery disease, arrhythmias, valvular heart disease, and heart failure), and brain disease (cerebrovascular disease) were obtained from premedication records. Operative data included type, duration, year of surgery; laparoscopic or robotic surgery; type of anesthesia (total intravenous anesthesia or inhalational anesthetics); number of packed red blood cell transfusions; and estimated blood loss. If the type of anesthesia changed during surgery, the final method used was recorded. If a patient underwent several surgeries during the study period, each surgery was treated individually. Postoperative data included the patient's destination after the operating room (ICU or PACU), the type of heating device used (heat pad, air- or blood warmer), and the length of hospital stay (from the day of surgery to the day of discharge).

Statistical analysis

Statistical analyses were performed using the IBM SPSS Statistics for Windows, ver. 27.0 (IBM Corp.) with a P-value of <0.05 considered statistically significant. The baseline characteristics of the patients are presented as means with standard deviations for continuous variables and as numbers with percentages for categorical variables. Hypothermia and non-hypothermia groups were compared using t-tests and chi-square tests for continuous and categorical variables, respectively. We performed a multivariable logistic regression analysis to identify factors associated with exposure to hypothermia after major abdominal surgery. In addition, we conducted multivariable logistic regression analysis for the occurrence of postoperative complications. We used 2 different models to study the effect of hypothermia on postoperative complications. In variable model 1, we classified the patients into the following 2 groups: the non-hypothermic group (reference) *vs.* the hypothermic group. The variable model 2 used the following 3 categories for body temperature: normothermia (reference), hypothermia, and hyperthermia. Subsequently, we performed a multivariable logistic regression analysis for each major postoperative complication (AKI, UTI, pneumonia, delirium, myocardial injury, and stroke).

RESULTS

Patient baseline characteristics and perioperative data

Fig. 1 illustrates the patient selection process. Of the 67,314 patients who underwent major abdominal surgery during the study period, 30,194 met our inclusion criteria. Using a tympanic thermometer, we classified 21,293 and 8,901 patients into the hypothermic and non-hypothermic groups, respectively (Table 1). The hypothermic group had a higher proportion of female patients (56.28% *vs.* 50.71%), longer hospital stays (12.19 days *vs.* 8.36 days), and a larger estimated blood loss during surgery (166.92 mL *vs.* 134.56 mL) than the non-hypothermic group. Patients in the hypothermic group were more likely to recover in the ICU postoperatively (6.40% *vs.* 3.82%) than those in the non-hypothermic group. Furthermore, fewer patients in the hypothermic group used heat pads postoperatively (90.96% *vs.* 95.00%) and were more likely to experience postoperative complications, such as AKI (9.96% *vs.* 9.75%) and UTI (0.99% *vs.* 0.66%) than those in the non-hypothermic group.

Factors associated with postoperative hypothermia

The incidence of postoperative hypothermia in the PACU or ICU during the first 30 minutes was 70.52%. As shown in Table 2, female patients (odds ratio [OR], 1.28; 95% confidence interval [CI], 1.20–1.36; P < 0.001), patients with anemia (OR, 1.15; 95% CI, 1.08-1.22; P < 0.001), and patients with abnormal serum creatinine levels (OR, 1.12; 95% CI, 1.03–1.22; P = 0.006) were more likely to experience postoperative hypothermia. Patients who underwent surgery under inhalational anesthesia (OR, 0.91; 95% CI, 0.84–0.97; P = 0.007) and those who underwent laparoscopic or robotic surgery (OR, 0.81; 95% CI, 0.76–0.86; P < 0.001) were less associated with the incidence of postoperative hypothermia. Patients undergoing gynecological procedures (OR, 1.42; 95% CI, 1.31–1.54; P < 0.001) were at higher risk of exhibiting postoperative hypothermia than those undergoing general surgical procedures.

Factors associated with postoperative complications

Table 3 illustrates the adjusted OR for postoperative body temperature in relation to postoperative complications. In variable model 1, the incidence of postoperative complications was 9% higher in the hypothermic group than in the non-hypothermic group (OR, 1.09; 95% CI, 1.01–1.19; P = 0.040). Similarly, the hypothermic group showed a 10% higher incidence of postoperative complications than the normothermic group in variable model 2 (OR, 1.10; 95% CI, 1.01–1.20; P = 0.025). Table 4 presents the effect of postoperative hypothermia (compared to non-hypothermia) on each major postoperative complication, considering the identical covariates

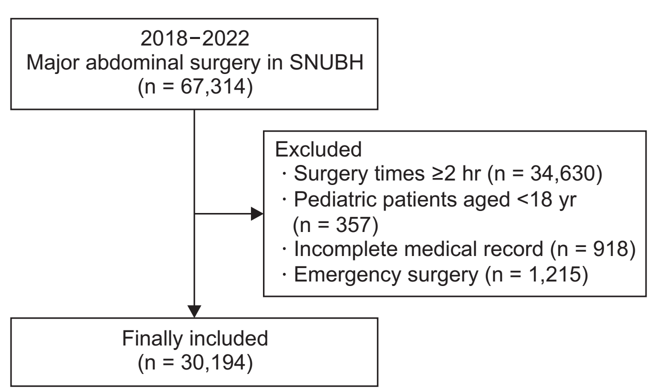

Fig. 1. Patient selection process. SNUBH, Seoul National University Bundang Hospital.

Table 1. Baseline characteristics and perioperative data

Variable	Hypothermia group	Non-hypothermia group	P-value
No. of patients	21,293	8,901	
Age (yr)	56.84 ± 14.95	54.29 ± 14.68	<0.001
Female sex	11,984 (56.28)	4514 (50.71)	<0.001
LOS after surgery	8.34 ± 12.19	8.08 ± 8.36	0.032
Past medical history			
Diabetes mellitus	2,146 (10.08)	927 (10.42)	0.378
Hypertension	4,368 (20.51)	1,761 (19.78)	0.151
Heart diseases	1,105 (5.19)	392 (4.40)	0.004
Brain diseases	847 (3.98)	274 (3.08)	<0.001
SCr level abnormality	3,025 (14.21)	1,070 (12.02)	<0.001
Anemia	5,746 (26.99)	1,979 (22.23)	<0.001
Anesthesia			0.002
TIVA	3,875 (18.20)	1,489 (16.73)	
Inhalation	17,418 (81.80)	7,412 (83.27)	
ASA physical status classification			<0.001
I	6,009 (28.22)	2,505 (28.14)	
II	11,721 (55.05)	5,137 (57.71)	
≥III	3,563 (16.73)	1,259 (14.14)	
Duration of surgery (min)	169.50 (87.80)	189.14 (95.51)	<0.001
Estimated blood loss (mL)	166.92 ± 743.79	134.56 ± 336.36	<0.001
Laparoscopic or robotic surgery	5,144 (24.2)	2,535 (28.5)	<0.001
No. of pRBC transfusion	2.8 ± 3.0	2.0 ± 2.4	<0.001
Postoperative exit			<0.001
PACU	19,931 (93.60)	8,561 (96.18)	
ICU	1,362 (6.40)	340 (3.82)	
Type of surgery			<0.001
General surgery	12,511 (58.76)	5,828 (65.48)	
Obstetrics and gynecology	4,606 (21.63)	1,408 (15.82)	
Urology	4,176 (19.61)	1,665 (18.71)	
Year of surgery			<0.001
2018	3,857 (18.09)	1,959 (22.01)	
2019	4,519 (21.22)	1,672 (18.78)	
2020	4,188 (19.67)	1,654 (18.58)	
2021	4,377 (20.56)	1,765 (19.83)	
2022	4,358 (20.47)	1,851 (20.80)	
Heating device			
Heat pad	19,368 (90.96)	8,456 (95.00)	<0.001
Air warmer	19,411 (91.16)	8,167 (91.75)	0.095
Blood warmer	730 (3.43)	166 (1.87)	<0.001
Postoperative complications	2,631 (12.36)	1,067 (11.99)	0.373
Acute kidney injury	2,120 (9.96)	868 (9.75)	<0.001
Urinary tract infection	210 (0.99)	59 (0.66)	0.006
Pneumonia	117 (0.55)	49 (0.55)	0.991
Delirium	304 (1.43)	129 (1.45)	0.886
Myocardial Injury	20 (0.09)	7 (0.08)	0.685
Stroke	2 (0.01)	0 (0)	0.361

Values are presented as number only, mean ± standard deviation, or number (%).
LOS, length of hospital stays; SCr, serum creatinine; TIVA, total intravenous anesthesia; ASA, American Society of Anesthesiologists; PACU, postanesthesia care unit; pRBC, packed red blood cell; ICU, intensive care unit.

listed in the previous multivariable logistic regression analyses. The hypothermic group showed a 14% higher incidence of AKI than the non-hypothermic group (OR, 1.14; 95% CI, 1.04–1.25; P = 0.007). All other ORs with 95% CIs in the model regarding AKI are presented in Supplementary Table 1.

Table 2. Multivariable logistic regression analyses for postoperative hypothermia

Variable	OR (95% CI)	P-value
Age	1.02 (1.02–1.02)	<0.001
Female sex (*vs*. male sex)	1.28 (1.20–1.36)	<0.001
LOS after surgery	1.01 (1.00–1.01)	0.006
Past medical history		
Diabetes mellitus	0.91 (0.83–1.00)	0.048
Hypertension	0.97 (0.89–1.03)	0.247
Heart disease	0.97 (0.86–1.11)	0.679
Brain disease	1.13 (0.98–1.31)	0.099
Serum creatinine level abnormality	1.12 (1.03–1.22)	0.006
Anemia	1.15 (1.08–1.22)	<0.001
Anesthesia		
TIVA	Reference	
Inhalation	0.91 (0.84–0.97)	0.007
ASA physical status classification		
1	Reference	
2	0.92 (0.86–0.98)	0.008
≥3	1.04 (0.94–1.15)	0.476
Duration of surgery, 30 min	0.92 (0.91–0.93)	<0.001
Estimated blood loss, 100 mL	1.03 (1.02–1.04)	<0.001
Postoperative exit		
PACU	Reference	
ICU	1.66 (1.44–1.91)	<0.001
Laparoscopic or robotic surgery	0.81 (0.76–0.86)	<0.001
No. of pRBC transfusions	1.13 (1.06–1.20)	<0.001
Heating device		
Heat pad	0.56 (0.50–0.63)	<0.001
Air warmer	1.00 (0.91–1.10)	0.952
Blood warmer	2.34 (1.96–2.79)	<0.001
Type of surgery		<0.001
General surgery	Reference	
Obstetrics and gynecology	1.42 (1.31–1.54)	<0.001
Urology	1.07 (0.99–1.15)	0.087
Year of surgery		
2018	Reference	
2019	1.37 (1.27–1.49)	<0.001
2020	1.30 (1.20–1.41)	<0.001
2021	1.26 (1.16–1.37)	<0.001
2022	1.18 (1.09–1.28)	<0.001

OR, odds ratio; CI, confidence interval; LOS, length of hospital stays; TIVA, total intravenous anesthesia; ASA, American Society of Anesthesiologists; PACU, postanesthesia care unit; ICU, intensive care unit.

Table 3. Multivariable logistic regression analyses for any postoperative complications

Variable	OR (95% CI)	P-value
Variable model 1		
Normothermia	Reference	
Hypothermia	1.09 (1.01–1.19)	0.040
Variable model 2		
Normothermia	Reference	
Hypothermia	1.10 (1.01–1.20)	0.025
Hyperthermia	1.43 (0.94–2.17)	0.093
Other covariates in model 1 (below)		
Age	1.01 (1.01, 1.01)	<0.001
Female sex	0.90 (0.82, 0.98)	0.017
Past medical history		
Diabetes mellitus	1.23 (1.10–1.38)	<0.001
Hypertension	1.06 (0.96–1.17)	0.218
Heart disease	0.99 (0.85–1.15)	0.863
Brain disease	0.80 (0.67–0.96)	0.015
Anemia	1.48 (1.34–1.63)	<0.001
Anesthesia		
TIVA	Reference	
Inhalation	1.65 (1.40–1.95)	<0.001
ASA physical status classification		
1	Reference	
2	1.13 (1.01–1.27)	0.033
≥3	2.17 (1.88–2.51)	<0.001
Duration of surgery, 30 min	1.13 (1.11, 1.14)	<0.001
Estimated blood loss, 100 mL	1.02 (1.01, 1.02)	<0.001
Type of surgery		
General surgery	Reference	
Obstetrics and gynecology	0.52 (0.43–0.62)	<0.001
Urology	8.21 (7.43–9.07)	<0.001
Laparoscopic or robotic surgery	1.65 (1.50, 1.82)	<0.001
No. of pRBC transfusion	1.47 (1.33, 1.63)	<0.001
Heating device		
Heat pad	0.43 (0.38–0.48)	<0.001
Air warmer	0.93 (0.81–1.08)	0.353
Blood warmer	0.89 (0.72–1.10)	0.275
Year of surgery		
2018	Reference	
2019	0.88 (0.78–0.99)	0.031
2020	0.86 (0.77–0.97)	0.013
2021	0.78 (0.69–0.88)	<0.001
2022	0.70 (0.61–0.79)	<0.001

OR, odds ratio; CI, confidence interval; TIVA, total intravenous anesthesia; ASA, American Society of Anesthesiologists; pRBC, packed red blood cell.

DISCUSSION

This retrospective study aimed to identify the risk and protective factors associated with postoperative hypothermia. Postoperative hypothermia was correlated with the occurrence of postoperative complications, particularly AKI.

Since 2018, the Korea Health Insurance Review and Assessment Service has been working to improve the quality of anesthesia-related medical care through anesthesia appropriateness assessments. One of the criteria items of this anesthesia appropriateness assessment is managing patients from being exposed to hypothermia; consequently, the frequency of hypothermia appears to have decreased until recently, including in our study.

After the induction of general anesthesia, anesthetic agents inhibit the thermoregulatory response by increasing the

Table 4. Multivariable logistic regression analyses for each postoperative complication

Variable	OR (95% CI)	P-value
Acute kidney injury[a)]		
Normothermia	Reference	
Hypothermia	1.14 (1.04–1.25)	0.007
Urinary tract infection		
Normothermia	Reference	
Hypothermia	1.25 (0.93–1.68)	0.148
Pneumonia		
Normothermia	Reference	
Hypothermia	1.05 (0.74–1.48)	0.790
Delirium		
Normothermia	Reference	
Hypothermia	0.83 (0.67–1.03)	0.088
Myocardial injury		
Normothermia	Reference	
Hypothermia	0.86 (0.35–2.09)	0.732
Stroke		
Normothermia	Reference	
Hypothermia	0.00 (0.00)	0.918

OR, odds ratio; CI, confidence interval.
[a)]All ORs with 95% CIs of other covariates were presented in Supplementary Table 1.

threshold to heat (sweating) and decreasing the threshold to cold (vasoconstriction and shivering). With neuromuscular blockers that inhibit tremors, general anesthesia alters thermoregulation and results in hypothermia, which exhibits a characteristic and progressive pattern. During the first hour, the body temperature drops rapidly (exponential phase). Subsequently, over the next 2 to 3 hours, the temperature decreases slowly and continuously in a linear manner until it reaches a plateau phase [14].

The results of this study can be explained based on the characteristics of gynecological and urological surgeries. Decreases in body temperature during surgery are mostly due to radiation, convection, evaporation, and conduction [15]. Laparotomy requires exposure of the peritoneal cavity to cool ambient air in the operating room. For abdominal inflation, laparoscopic surgery uses carbon dioxide at a temperature of 21 °C without additional warming [16]. Patients are frequently required to be in the lithotomy position, leaving a limited body surface area to be heated intraoperatively. Furthermore, urological surgeries frequently require large amounts of irrigation fluid, which contributes to hypothermia. The clinical practice guideline recommends that irrigation fluids be pre-warmed at 38–40 °C; however, the preventive effect of warmed irrigation fluids is not highly effective at low flow rates (<500 mL/hr) [15].

Our study found that patients who underwent major abdominal surgery and experienced postoperative hypothermia were more prone to AKI, which is contrary to the study by Oh et al. [17], which showed that body temperature under 35 °C had a protective effect against AKI. This discrepancy may be explained by the pathophysiology of AKI, which is a transient or sustained renal hypoperfusion that reduces renal blood flow. These further decreases oxygen delivery to tubular structures, potentially causing an imbalance between oxygen demand and supply. Hypothermia can preserve kidney function by decelerating metabolism, thereby reducing oxygen demand and energy depletion. However, the validity of this theory is influenced by the blood volume of the patient. In our study, all patients underwent major abdominal surgeries, suggesting that they experienced more inadvertent bleeding and intestinal evaporation than those who underwent minor surgical procedures. Hypothermia can cause further peripheral vascular constriction, thereby intensifying the reduction in renal blood flow. This phenomenon was also observed by Cui et al. [18] in newborns undergoing gastrointestinal surgeries.

Nonetheless, this study has some limitations. First, this was a retrospective study. For example, we used data from an automated electronic medical record system; however, the quality and precision were below those obtained from a prospective study. Second, we could not use urine output and creatinine levels to diagnose postoperative AKI. The sensitivity of the diagnosis may be lower because the serum creatinine level was not measured at the same time points and intervals for all patients on postoperative days 0 to 2. Third, infrared tympanic thermometers were used to reflect the patient's core temperature, which was measured most accurately using a pulmonary artery catheter. Although widely used in clinical practice, infrared tympanic measurements have shown variability in readings and a lag behind rapidly changing core temperatures, which could not have correctly reflected hypothermia [19]. Finally, we could not include intraoperative temperature data during surgeries in the study due to inconsistencies in measurement methods or intervals. This could be considered a limitation, as patients' intraoperative body temperature could have affected their postoperative body temperature.

In conclusion, this study showed that the presence of hypothermia for a short initial period during the postoperative recovery period in patients receiving major abdominal surgery under general anesthesia was associated with an increased incidence of postoperative complications. This association was more evident in the occurrence of AKI. Therefore, close monitoring of patients by frequently measuring body temperature to detect hypothermic patients and providing adequate heating methods in the PACU or ICU during the initial recovery phase are necessary to prevent postoperative AKI.

SUPPLEMENTARY MATERIALS

Supplementary Table 1 can be found via https://doi.org/10.4174/astr.2024.107.2.120.

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Conflict of Interest

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

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Investigation: IAS
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