# Novel Monitoring of the Core Body Temperature and Predictors of Hypothermia in Patients Undergoing Lung Cancer Surgery: A Prospective Observational Study

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# Abstract

**Objectives:** Our study aimed to explore the feasibility and effect of noninvasive and wireless intelligent monitoring of core body temperature in surgical patients, and to evaluate the effect of intraoperative hypothermia on rapid recovery index of the patients undergoing lung cancer surgery.

**Methods:** From January 2020 to June 2020, a wireless temperature sensor was pasted onto the nonoperative side of the axilla preoperatively to monitor axillary temperatures to help estimate core temperature in lung cancer patients. The intraoperative body temperature changes and related factors were collected and analyzed. Independent associations between hypothermia exposure and the duration of hospitalization and direct medical costs were evaluated. Our research was carried out and report according to the STROBE guideline.

**Results:** In total, 206 consecutive patients who underwent lung cancer surgery were recruited, and the incidence of hypothermia was 83.01%. The median proportion of patients experiencing hypothermia was 62.65%, with the largest decrease in temperature recorded as 1.034±0.569°C. The patients' lowest body temperature was calculated as follows: (Y) = 35.423 - 0.003 × surgical duration + 0.045 × BMI - 0.012 × age, $R^2$=0.182. Patients with hypothermia had longer hospital stays and higher medical costs (t=2.201, P=0.029 and t=5.048, P<0.001, respectively).

**Conclusions:** Hypothermia contributes to extended hospital stays and increased medical costs for patients. The use of noninvasive and wireless intelligent monitoring throughout an operation and adoption of heat preservation measures are expected to prevent and reduce hypothermia and promote rapid patient recovery.


# Introduction

The core body temperature better represents the temperature of the human body than the body surface temperature.[1] When the core body temperature of a patient is less than 36°C due to various perioperative factors, this is known as perioperative hypothermia, a common phenomenon in patients undergoing surgery, especially under general anesthesia.[2,3] Perioperative hypothermia can lead to many adverse outcomes, including perioperative adverse cardiovascular events (normal vs hypothermia was 1.4% vs 6.3%),[4] surgical site infection (normal vs hypothermia was 6% vs 19%),[5] coagulation dysfunction and increased blood transfusion requirements,[6] decreased anesthetic efficacy, metabolic changes, delayed awakening times, and increased chills and discomfort,[7,8] which can seriously affect the safety of surgical patients and decrease recovery quality.

For surgical patients under general anesthesia, hypothermia can result as a loss of consciousness, a lack of behavioral adjustment, and pharmacological inhibition of the central thermoregulatory responses as well as the chill response.[9] All general anesthetics tested thus far markedly and briefly impair normal autonomic thermoregulatory control and can reduce thermoregulatory responses. As a result, the thermoregulatory response threshold range increased from 0.2 ℃ to 4 ℃. Furthermore, narcotic drugs can directly dilate blood vessels, and muscle relaxants affect chill response inhibition. Patients under general anesthesia are more likely to experience hypothermia than those who are not,[10] especially those who undergo open operations with large areas or body cavities exposed. Both the new prevention guidelines for perioperative hypothermia in Germany[11] and the national clinical guidelines in Britain[12] stress the importance and necessity of perioperative hypothermia prevention. In addition, perioperative hyperthermia caused by fever or malignant hyperthermia, though not common, is often severe when it occurs. With some exceptions, anesthesiologists and operating room nurses are advised to maintain the patient's temperature within the normal range.[13] Therefore, it is necessary to monitor core body temperature throughout the operation, and an accurate measurement of core body temperature, even when in the normal range, is particularly important for surgical patients. Although the effective monitoring of intraoperative temperature changes is a prerequisite for maintaining constant and normal patient temperatures, it is difficult to manage the temperature of surgical patients.

Different methods of intraoperative core temperature monitoring have been developed and utilized. Core body temperature can be monitored intraoperatively at many sites, and a variety of devices are available. However, the most accurate measurements of core body temperature are also the most invasive and involve the pulmonary artery, esophagus, nasopharynx and eardrum.[14] In many cases, invasive methods are not appropriate to measure core body temperature, and noninvasive methods are usually used instead. Minimally invasive and non-core body temperature measurements can usually replace invasive core body temperature measurements and include "deep" temperatures of the bladder, mouth and rectum.[15] Other commonly used methods include oral temperature measurement, infrared ear temperature measurement, underarm temperature measurement, temporal artery thermometry and liquid crystal frontal temperature stripping. These methods are convenient, rapid, painless, and basically safe and risk free. However, the accuracy of intraoperative body temperature varies with different collection devices and sites. In addition, whether intraoperative core temperature can be continuously monitored throughout the whole course is an issue worthy of discussion.

The blood temperature of the axillary artery reaches or is near core body temperature. In a warm environment, as in a hospital, the temperature measured near the axillary artery after a period of adduction and clamping of the arm can be used to approximate core body temperature.[16] In contrast, the randomly measured axillary temperature can be used to approximate skin temperature and is often 3°C lower than core body temperature. With the traditional method, even the axillary temperature obtained by careful measurement does not better reflect core body temperature.[17] A meta-analysis also confirmed considerable variability.[18] The relationship between axillary temperature and core body temperature therefore depends largely on the measurement technology and clinical environment. A novel wireless temperature sensor (iThermonitor, CW100X) was used in conjunction with a temperature monitoring device that provides better core temperature estimation than traditional axillary thermometers. This improvement is due to the continuous temperature measurement and recording of the iThermonitor temperature sensor at a frequency of once every 4 seconds and the use of a patented algorithm to compensate for the temperature error of the ambient temperature and the change in the measurement position. The accuracy of the iThermonitor in the intraoperative monitoring of core temperature in adult noncardiac surgery was confirmed, and the difference between the core temperature reflected by using the iThermonitor temperature sensor to monitor the body surface temperature and esophageal core temperature is only 0.14°C ± 0.26°C.[19] Our previous study was conducted on 3621 pairs of body temperatures measured, which showed that the temperatures measured with the iThermonitor agreed with those measured with the mercury thermometers overall, with a mean difference of 0.03°C ± 0.35°C and a moderate correlation ($r = 0.755$, $P < 0.001$),[20] implying that the iThermonitor is promising for continuous, remote, noninvasive, wireless and intelligent temperature monitoring in surgical patients.

To our knowledge, there is currently a lack of research on monitoring core body temperature via the body surface using noninvasive and wireless body temperature sensors in patients undergoing lung cancer surgery. The changes in intraoperative core body temperature and the influence of hypothermia on rapid recovery indicators of patients undergoing lung cancer surgery remain unclear. These limitations of existing results can, to some extent, be addressed by analyzing the feasibility and significance of core temperature monitoring. Therefore, it is necessary to explore a feasible and reliable method to monitor and investigate changes in core body temperature of the patients undergoing lung cancer surgery to effectively manage their body temperature and prevent hypothermia. Thereafter, we used research data from a registry to examine the feasibility and effectiveness of wireless and noninvasive body surface monitoring (using the iThermonitor® temperature sensor) of core body temperature in patients undergoing lung cancer surgery and the contribution of hypothermia exposure to prolonged hospital stays and increased medical costs.

## Material And Methods

# Participants

Ethical approval was obtained from the Biomedical Research Ethics Committee of the West China Hospital of Sichuan University on 14 September 2018 (No. 2018–287). Participating patients provided written consent. Our research was carried out and report according to the guideline (STROBE Strengthening the Reporting of Observational Studies in Epidemiology).

This study was carried out in the operating room of the West China Hospital of Sichuan University between January 2020 and June 2020. Participants were recruited according to the following inclusion and exclusion criteria. 1) Inclusion criteria: patients with an American Society of Anesthesiologists (ASA) physical status of I–III who were scheduled for open or thoracoscopic lung cancer surgery under general anesthesia; and provided informed consent to participate in this study. 2) Exclusion criteria: the expected surgical time was less than 1 hour; patients with abnormal temperature regulation or a body temperature over 38 ℃ 3 days before surgery; and patients with skin allergies.

# Intraoperative body temperature monitoring

After obtaining informed consent from the patients before surgery, the wireless temperature sensor (iThermonitor®) was pasted onto the nonoperative side of the axilla preoperatively to monitor axillary temperature throughout surgery, which helps to estimate the core temperature of lung cancer patients. The iThermonitor® wireless temperature sensor (Fig. 1A) was paired to an iPhone (Fig. 1B), and the temperature signal was transmitted by Bluetooth, which could continue running for 30 days. Hypoallergenic medical patches were used to securely attach the sensor to the hair-shaved nonoperative side of the axilla (Fig. 1C) before anesthesia induction. Patients were asked to adduct the ipsilateral arm for up to 5 minutes after the sensor was pasted, and the temperature was displayed stably on the corresponding iPhone. Thereafter, patients were free to move their arms. Otherwise, the temperature signal was also transmitted to the monitor by the signal receiver (cHub smart box), and then the temperature signal was displayed on the screen of the monitor; thus, the temperature data were visualized (Fig. 2). Generally, prewarming and intraoperative insulation (with an air heating blanket) were not used due to the short operation time (approximately 1–4 hours), and the intention to use an insulation blanket was uncertain. The operating room environment temperature was maintained near 22°C with a humidity of 40%~60%.

Evaluation indexes

1) Main outcome measure: The measured value of the patient's body temperature (°C) and the proportion of hypothermia duration.

2) Secondary outcome measures: The patient's general demographic data, the maximum drop in body temperature, surgical time, postoperative complications, length of hospital stay and medical cost for the patient.

# Statistical analysis

Data are summarized as the frequency for categorical variables and as the mean ± standard deviation (SD) for continuous variables. Differences in categorical variables were compared using the chi-square test, and differences in continuous variables were compared using the *t*-test. Multiple linear stepwise regression analysis was performed to determine the association of the surgical variables with hypothermia. All statistical analyses were conducted using SPSS 17.0 (SPSS Inc., Chicago). Two-sided *P* values < 0.05 indicated statistical significance.

# Results

Of the 240 eligible patients, data from 206 patients were ultimately included in the analysis (Fig. 3). A total of 206 consecutive patients undergoing lung cancer surgery (91 males and 115 females) were included in this study. The mean patient age was 55.83 ± 11.24 years [26, 82]. The incidence of hypothermia in lung cancer surgery patients was 171/206 (83.0%). The median proportion of patients who experienced hypothermia was 62.65%, and the interquartile interval was 80.450%-24.925% (55.525%) (the data were not normally distributed). The average maximal drop in body temperature was

1.034 ± 0.569 °C and ranged from 0.004°C, 2.833 °C, reflecting the high incidence of hypothermia in patients undergoing thoracic surgery (in the absence of active insulation).

# Univariate analysis of hypothermia

The incidence of hypothermia in patients younger than 60 years was 102/131 (77.9%), while it was 69/75 (92.0%) in patients older than 60 years, with a statistically significant difference ($X^2 = 6.800, P = 0.033$). Therefore, patients older than 60 years were more likely to have hypothermia than those younger than 60 years. There was no statistically significant difference in other single-factor comparisons, all with $P$ values > 0.05.

# Regression analysis of hypothermia

The lowest intraoperative body temperature was used as the dependent variable, and the following variables was used as independent variables to carry out the multiple linear stepwise regression analysis: sex, age, body mass index (BMI), type of surgery, duration of surgery, washing fluid temperature, ASA grade, bleeding amount, and infusion of antibiotics. The results showed that the duration of surgery, BMI and age were correlated with a low temperature. The regression equation used to determine the patient's lowest body temperature was as follows: (Y) = 35.423 − 0.003 * duration of surgery + 0.045 * BMI − 0.012 * age. As seen from the regression equation, the duration of surgery and age were negatively correlated with the patient's lowest intraoperative body temperature, while BMI was positively correlated with the lowest intraoperative body temperature. In addition, $R^2 = 0.182$, which indicated that the independent variable could explain 18.2% of the variation in the dependent variable. The standardized linear regression coefficient (beta) of the duration of surgery was − 0.315, the beta value of BMI was 0.233, and the beta value of age was − 0.227. Therefore, the duration of surgery had the greatest impact on the lowest intraoperative temperature of the patients, followed by BMI and age.

Distribution and comparison of the length of stay and direct medical expenses after surgery in patients with different body temperatures

Compared with patients without hypothermia (T ≥ 36°C), patients with hypothermia (T < 36°C) had a longer average length of postoperative hospitalization ($t = 2.201$, $P = 0.029$) and a higher average postoperative hospitalization cost ($t = 5.048$, $P < 0.001$), as shown in Table 1.

Table 1
Length of Stay and Direct Medical Expenses in Postoperative Patients with Different Body Temperatures ($n = 206$)

| Group | Average length of postoperative hospitalization (days) (X ± S) | Average postoperative direct medical expenses ($) (X ± S) |
|---|---|---|
| **T < 36℃ (n = 171)** | 4.8 ± 1.6 | 1084.7 ± 336.9 |
| **T ≥ 36℃ (n = 35)** | 4.1 ± 2.2 | 827.0 ± 260.7 |
| t | 2.201 | 5.048 |
| P | **0.029** | **0.000** |

# Univariate analysis of hypothermia duration

In the intraoperative period, the proportion of nonelderly patients (< 60 years) whose duration of hypothermia was longer than the median duration of hypothermia (62.6%) was 42.7% (56/131), and the proportion of elderly patients (≥ 60 years) was 62.7% (47/75). The difference in the duration of hypothermia between the two groups was statistically significant ($X^2 = 7.569, P = 0.006$). As a result, hypothermia lasted longer in older patients. There was no statistically significant difference in other single-factor comparisons, all with $P$ values > 0.05.

Distribution and comparison of the length of stay and direct medical expenses after surgery in patients with different hypothermia durations

Compared with patients whose hypothermia duration was longer than the median duration of hypothermia (> 62.6%), patients whose hypothermia duration was shorter than the median duration of hypothermia (< 62.6%) had a shorter average length of stay ($t$ = 2.756, $P$ = 0.006) and mean length of postoperative hospitalization ($t$ = 3.295, $P$ = 0.001); moreover, they had lower average total hospital expenses and average postoperative hospitalization costs ($t$ = 2.300, $P$ = 0.023; $t$ = 6.722, $P$ < 0.001, respectively), as shown in Table 2.

Table 2
Length of Stay and Direct Medical Expenses in Postoperative Patients with Different Hypothermia Durations (*n = 206*)

| Group | Average total length of hospitalization (days) (X ± S) | Average length of postoperative hospitalization (days) (X ± S) | Average total direct medical expenses ($) (X ± S) | Average postoperative direct medical expenses ($) (X ± S) |
|---|---|---|---|---|
| **Hypothermia duration > 62.6% (n = 97)** | 11.8 ± 3.8 | 5.4 ± 1.8 | 7314.6 ± 2864.3 | 1170.1 ± 300.3 |
| **Hypothermia duration < 62.6% (n = 99)** | 10.4 ± 3.3 | 4.4 ± 2.4 | 6382.1 ± 2811.9 | 891.4 ± 280.0 |
| $t$ | 2.756 | 3.295 | 2.300 | 6.722 |
| $P$ | **0.006** | **0.001** | **0.023** | **0.000** |

## Discussion

# Exploration of the bases and novel methods of core temperature monitoring in surgical patients

The human body can maintain a constant body temperature by changing the blood distribution and carrying out various other levels of heat preservation measures. Behavioral regulation is the most powerful thermoregulatory effector. However, in surgical patients, body temperature depends largely on autonomic responses, including sweating, vasoconstriction, and shivering. Among these defenses, vasoconstriction is the most important and accounts for most perioperative thermal perturbations. General anesthetics have little influence on sweating but profoundly increase (ten- to twenty-fold) the vasoconstriction and shivering thresholds, and thermoregulatory defenses are reasonably well maintained in infants and children but somewhat impaired in the elderly.[19] When environmental temperature changes, nerve transport via skin vasoconstriction is induced, and more than 50% of the human body's heat is transmitted to various tissues through blood flow,[21] thereby leading to an adaptive change in core temperature within 7–8 minutes.[22] On the other hand, for surgical patients under anesthesia who experience a prolonged stress reaction, the lack of self-behavior does not protect against temperature changes. Therefore, it is very important to monitor and maintain the perioperative body temperature of patients.

Human skin temperature is an important parameter that reflects the exchange between the human body and external temperature and is often measured in a transient thermal environment.[23] The core temperature is the truer, more stable body temperature, but it is usually difficult to accurately measure,[24] and most wired or invasive measurement methods are adopted. A variety of "near-core" sites are used clinically and include the tympanic membrane, pulmonary artery, distal esophagus, nasopharynx, mouth, axilla, bladder, and rectum.[19] Axillary temperatures are reasonably accurate and work best when the probe is positioned over the axillary artery and the arm is adducent.[19] The combined inaccuracy of a site/thermometer combination should not exceed 0.5°C, which is a good rule of thumb that has been used in many studies, although the level of accuracy that is clinically necessary has yet to be established. One basis for this choice is that the smallest difference has been shown to be associated with hypothermia-induced complications.[19] A new wireless thermometer, iThermonitor® (Raiing Medical, Chengdu, China), uses a proprietary system to adjust for ambient temperature, the skin interface, and positional changes, including arm abduction, in an effort to enhance the accuracy of core temperature estimates from the axilla. The results of 3339 control data points showed that the precision of the iThermonitor® wireless temperature sensor vs. esophageal temperature (a good proxy for core body temperature) was 0.14℃±0.26℃, and the absolute difference was within 0.5°C in 91% of the measurements (95% CI, [0.88,0.93]). Thus, axillary temperature, as recorded by the iThermonitor®, estimates the core temperature of surgical patients well and appears suitable for clinical use,[25] which is supported by our preliminary results.[20] This instrument (iThermonitor® wireless temperature sensor) can measure core temperatures (or at least a surrogate) and therefore be used to monitor temperature and prevent hypothermia and complications.

In the present study, we used a wireless and noninvasive body surface (axilla) paste temperature sensor (iThermonitor®) to monitor core temperature in surgical patients. As a result, good results were achieved, and complete time series of events and temperatures were obtained. The display mode of the temperatures of lung cancer surgical patients changed from the original measurement point to a continuous curve, and the results were presented to visualize the temperature of a patient at a certain point in time or at the time of an event and thus to better intervene or prevent the occurrence of hypothermia and promote rapid recovery (Figs. 1 and 2).

# Predictors of intraoperative hypothermia in lung cancer surgical patients

In our study, a wireless temperature sensor (iThermonitor®) was pasted onto the nonoperative side of the axilla preoperatively to monitor axillary temperatures, which helps to estimate the core temperature of lung cancer patients. The results showed that the proportion of patients undergoing lung cancer surgery who experienced hypothermia was high (171/206; 83.01%), higher than the research results of Sun et al.[26] (64%). The possible reason for this difference was that in our study, on monitoring core body temperature, preoperative prewarming and intraoperative insulation (with an air heating blanket) were not used due to the short operation time (approximately 1–4 hours), and the intention to use an insulation blanket was uncertain, while in Sun et al.'s[26] study, the incidence of hypothermia was measured and recorded after warming with forced air. Another reason may be that our study included and analyzed only lung cancer surgical patients, while Sun et al.'s[26] study included other general patients, and the surgical approach may have had an effect on the core body temperature of the patients.

Regression analysis showed that the duration of surgery had the greatest impact on the intraoperative hypothermia of patients undergoing lung cancer surgery, followed by BMI and age. In particular, the longer the duration of surgery, the smaller the BMI, and the more elder the patient, the greater the risk of hypothermia. In addition, analysis of the influence of hypothermia duration on the length of hospital stay and medical expenses showed that the length of hospital stay and medical expenses increased when hypothermia occurred and hypothermia duration was extended in lung cancer surgical patients, consistent with the results of another relevant study.[27] Another study[28] also showed that changes in human core body temperature are affected by environmental temperature, patient age, BMI, cardiovascular conditions and disease status. Therefore, during surgery, especially for emaciated elderly patients with long operation times, temperature changes should be detected to maintain the stability of normal vital signs.

# Maintenance of core body temperature homeostasis in surgical patients

The proportion of patients undergoing lung cancer surgery who experienced hypothermia was high when preoperative prewarming and intraoperative insulation (with an air heating blanket) were not used. A previous study showed that the operating room ambient temperature was 22 ℃ and became the threshold of heat gain and loss. When the temperature of the operating room environment was less than 22 ℃, the core temperature of patients dropped to below 36 ℃; however, when the environment temperature was higher than 22 ℃, it was reported to be inconsistent with the temperature changes in patients.[28] Radiation is the main form of heat dissipation in patients under anesthesia. When the operating room temperature is set at 22 ℃, radiant heat dissipation can account for 70% of the total heat loss, and several layers of the surgical cloth do not effectively keep warm for a long time during major surgery. Hence, it would be wise to increase the temperature of the room within the limit to reduce radiation and conduction heat dissipation.[29] In our operating rooms, we set the environmental temperature to approximately 23°C, which is expected to help prevent hypothermia in surgical patients.

In patients undergoing lung cancer surgery whose body cavity was exposed, a large amount of physiological saline was used to wash the body cavity repeatedly during the operation. If a patient is covered with a sterile towel that is soaked with the rinse solution, the patient is more prone to hypothermia. Anesthesia also affects the body temperature regulation center and weakens the body temperature regulation function; for instance, general anesthesia can reduce the core body temperature by 2℃~3℃.[30] Perioperative core hypothermia causes serious surgery-related complications, decreases drug metabolism, prolongs recovery, and provokes thermal discomfort. The standard of care is thus to maintain a patient's core body temperature within the normal limit unless there is specific reason not to do so.[25] Various guidelines, including the Surgical Care Improvement Project and National Institute of Health and Clinical Excellence, suggest that patients be normothermic, defined as having a core temperature of at least 36°C at the end of surgery.[26] Core body temperature should be monitored, and hypothermia should be effectively prevented when surgical patients experience general anesthesia for more than 30 minutes and when the operation time is more than 1 hour. In clinical practice, it is thus now standard of care to warm surgical patients. Therefore, air heating insulation blankets and warming with forced air are often used to prevent patients from developing hypothermia during an operation.[26,31] Our study suggests that in future research and clinical practice, wireless and noninvasive surface auxiliary core body temperature monitoring (iThermonitor®) should be performed on surgical patients. The patient’s body temperature should be managed according to temperature changes. For example, during hypothermia, insulation measures (e.g., using an air heating blanket, applying liquid heating, increasing the room temperature, and adding a quilt cover), either alone or in combination, can be used. When the patient’s body temperature increases, heat preservation should be suspended or the temperature should be cooled down to maintain the temperature of the patient in the normal range and ensure their safety and promote rapid recovery.

# Research limitations

Some limitations of this study need to be noted. First, the wireless and noninvasive monitoring of body temperature in patients undergoing surgery was conducted only in one hospital, and only lung cancer surgical patients were selected for this study, so the extrapolation of results is limited. Second, we performed only intraoperative core body temperature monitoring for patients undergoing lung cancer surgery and did not conduct dynamic body temperature analysis and follow-up for long-term prognostic indicators, such as the impact of hypothermia on the patient’s quality of life, the unplanned readmission rate within one month after surgery, and disease prognosis. Finally, we did not explore and discuss improvement measures other than conventional thermal insulation measures. In the future, we can further study the effect of different thermal insulation measures on the prevention of hypothermia and the improvement in prognosis in lung cancer surgical patients.

# Conclusions

Hypothermia contributes to extended hospital stays and increased medical costs for patients. The use of noninvasive and wireless intelligent monitoring throughout an operation and adoption of heat preservation measures are expected to prevent and reduce hypothermia and promote rapid patient recovery.

# Abbreviations

BMI : Body Mass Index

ASA : American Society of Anesthesiologists

SD : standard deviation

STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

T : temperature

# Declarations

## Ethics approval and consent to participate

Ethical approval was obtained from the Biomedical Research Ethics Committee of the West China Hospital of Sichuan University on 14 September 2018 (No. 2018–287), and written consent were obtained from every participants. This research was carried out and report according to the guideline (STROBE Strengthening the Reporting of Observational Studies in Epidemiology).

## Consent for publication

Not Applicable

## Availability of data and material

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

## Competing interests

The authors declare that they have no competing interest.

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## Role of the funding source

The sponsors of the study had no role in the study design, collection, analysis and interpretation of data, writing of the report, or the decision to submit the article for publication.

## Authors' contributions

CQL and LL designed the study, collected the data, analyzed and interpreted the data, and drafted and revised the manuscript. HFR, CW, YWL and ZN helped with the data collection, analysis and interpretation. KL and RRG made substantive intellectual contributions to the interpretation of the data and the drafting of the manuscript. All authors read and approved the final manuscript.

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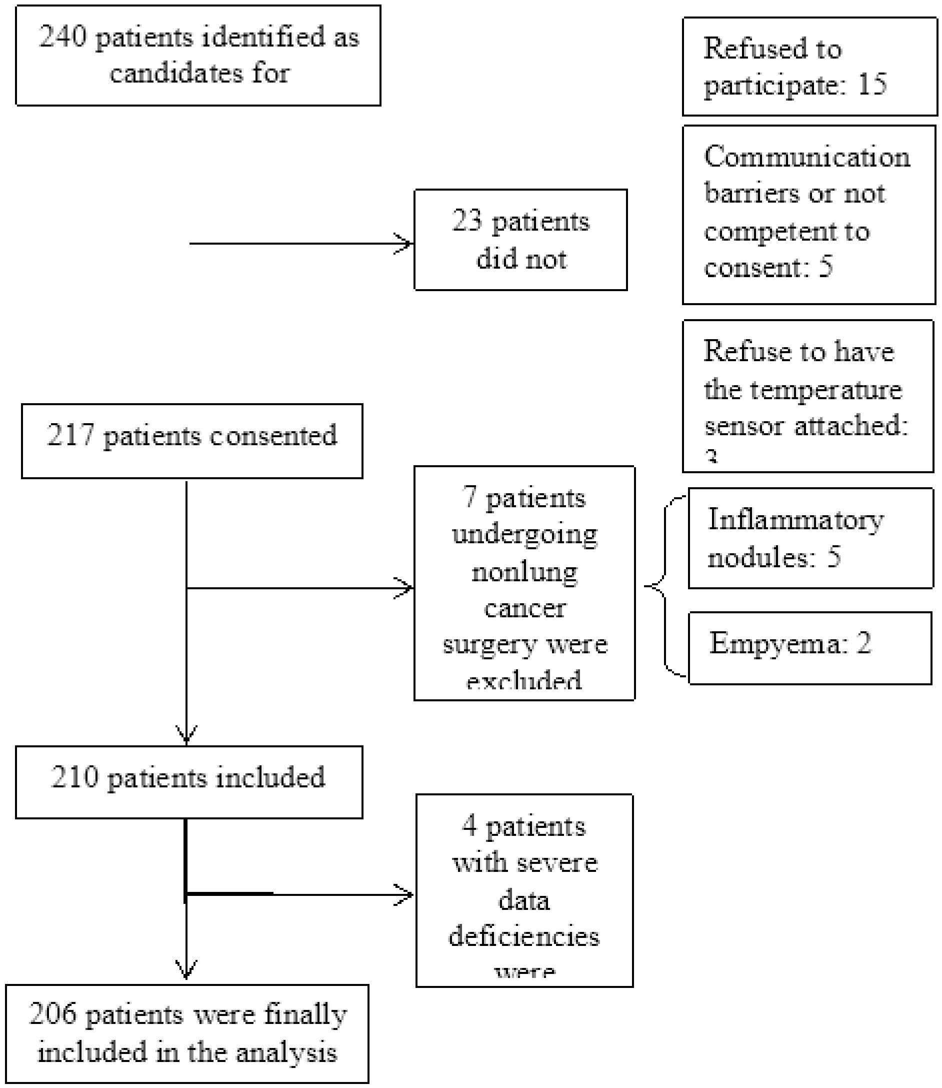
# Figures

### Figure 1

A disposable skin temperature sensor produced by Raiing Medical Technology Co., Ltd. iThermonitor mobile app interface of real-time body temperature display. A, The iThermonitor® wireless temperature sensor. The dimensions are 51.9 mm × 31.6 mm × 6.5 mm, and it weighs approximately 7 g, including the battery. B, A screenshot of the iPhone interface. C, A photograph showing the iThermonitor sensor taped on the axilla.


**Figure 2**

Temperature monitoring and display management system in the operating room. A, Signal receiver cHub smart box. B, A photograph showing the temperature monitoring module interface of the monitor. C, A screenshot of the temperature monitoring curve interface.




## Figure 3

Consolidated Standards of Reporting Trials (CONSORT) flow diagram of this study.