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Original Article

Evaluation of different body temperature measurement methods for patients in the intraoperative period*

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Highlights: (1) High correlation between central cutaneous and esophageal/nasopharyngeal thermometers. **(2)** It is not recommended to use infrared temporal thermometers in the perioperative period. **(3)** The type of thermometer can compromise the intraoperative temperature evaluation.

Objectives: this study aimed at estimating and comparing the reliability of temperature measurements obtained using a peripheral infrared temporal thermometer, a central cutaneous thermometer ("Zero-Heat-Flux Cutaneous thermometer") and an esophageal or nasopharyngeal thermometer among elective surgical patients in the intraoperative period. **Method**: a longitudinal study with repeated measures carried out by convenience sampling of 99 patients, aged at least 18 years old, undergoing elective abdominal cancer surgeries, with anesthesia lasting at least one hour, with each patient having their temperature measured by all three methods. **Results**: the intraclass correlation coefficient showed a low correlation between the measurements using the peripheral temporal thermometer and the central cutaneous (0.0324) and esophageal/nasopharyngeal (-0.138) thermometers. There was a high correlation (0.744) between the central thermometers evaluated. **Conclusion**: the data from the current study do not recommend using infrared temporal thermometers as a strategy for measuring the body temperature of patients undergoing anesthetic-surgical procedures. Central cutaneous thermometers and esophageal/nasopharyngeal thermometers are equivalent for detecting intraoperative hypothermia.

Descriptors: Nursing; Body Temperature Changes; Temperature; Perioperative Nursing; Surgicenters; Thermometers.

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Introduction

Implementing methods for maintaining the patients' body temperature between 35°C and 36°C during the perioperative period prevents hypothermia-associated complications[1-2]. The occurrence of hypothermia increases the patients' morbidity and mortality and is associated with an increase in health care costs and a decrease in patient satisfaction with the anesthetic-surgical procedure experience[1-3].

International guides which recommend measures to maintain body temperature reinforce the importance of measuring the patients' temperature throughout the perioperative period[4], preferably with the same system[1]. However, this is rarely the case in the clinical practice, with different body temperature measurement methods oftentimes being used, such as axillary, temporal and tympanic (by infrared) in the pre- and post-operative periods and invasive measurement methods in the intraoperative period. Furthermore, the patients' intraoperative temperature is not monitored, especially in shorter surgeries[5].

In addition to the challenges reported above, another even more fundamental challenge is the practice of maintaining perioperative normothermia, which concerns the quality of recording the patients' body temperature; this is not only an essential aspect for controlling patients' body temperature, but also for reviewing protocols and continuously improving the services offered to the clientele[6-7].

Therefore, it is currently known that surgical patients' temperature monitoring can be invasively or non-invasively performed, reflecting core or peripheral body temperature. The pulmonary artery stands out among the methods for measuring core temperature, such as nasopharynx or esophageal thermometers, considered the Gold Standard among the measuring methods. These measurements require using invasive devices that are introduced into body cavities or organs which continuously display temperature readings and variations[7-8]. The ways of measuring peripheral temperature consist of oral, rectal, axillary and tympanic assessments, several of which are considered non-invasive[9-10].

Thus, the most reliable temperature measurement methods that reflect core temperature, such as pulmonary artery, nasopharynx and esophagus, are invasive and not indicated for various types of surgical procedures. On the other hand, non-invasive measurement methods, such as axillary and oral measurements, generally reflect peripheral body temperature, but are subjected to different types of interference from the environment and also from the measurement site[1,8-9].

In this sense, a technological innovation seeks to respond to the challenges we face in measuring and recording the patients' temperatures during the perioperative period; namely, the Zero-Heat-Flux Cutaneous Thermometer is capable of reflecting core temperatures by measuring thermal radiation from the skin surface at the temple or on the side of the neck and appears to be sufficiently accurate for clinical use[10].

Therefore, preventing perioperative hypothermia remains a challenge, requiring an improvement in practices to achieve success in maintaining normothermia. For example, adequate monitoring and recording of a patient's temperature during the perioperative period.

Thus, the current study intends to contribute to improving the care provided to surgical patients, seeking to deepen the available evidence on intraoperative temperature measurement methods with the objective of assisting nurses' decision-making in implementing interventions in the Perioperative Nursing daily activities. Therefore, this study aimed at estimating and comparing the reliability of temperature measurements obtained using a peripheral infrared temporal thermometer, a central cutaneous thermometer ("Zero-Heat-Flux Cutaneous Thermometer") and an esophageal or nasopharyngeal thermometer among elective surgical patients in the intraoperative period.

Methods

Study design

A longitudinal and repeated measures study developed between 2019 and 2021 at a hospital specialized in cancer care and research and located in the state of São Paulo, Brazil.

Sample

A convenience sample of 99 patients aged at least 18 years old was included at the time of data collection, subjected to elective, curative or palliative abdominal cancer surgeries, with anesthesia lasting at least one hour. Subjects with body temperature equal to or greater than 38ºC at their admission to the operating room were excluded, as well as those undergoing video laparoscopic or minimally invasive surgeries.

Data collection

The day before the surgical procedure, the researchers checked the list of patients who were to undergo procedures the following day. The subjects that met the inclusion and exclusion criteria were subsequently approached by the researchers in the surgical ward or Intensive Care Unit (ICU) and invited to participate in the study, receiving explanations regarding the risks and benefits of participating in the research, with due presentation of the Free and Informed Consent Form (FICF) to the patients or their guardians.

The patients' intraoperative temperature was simultaneously measured on the surgery day using a peripheral digital infrared temporal thermometer (TT) (standard care) (GTech® Model FR1DZ1), an esophageal thermometer (ET) (Nihon Kohden®) allocated by the anesthesiologist, and a central cutaneous thermometer (CCT) (Zero-Heat-Flux-Spot On Thermometer 3M®) located on the right temporal region. Temperatures were recorded by all devices from the time the patient arrived in the operating room (OR), at the beginning of anesthesia induction, at the beginning of the surgery and, subsequently, every 20 minutes until the end of the anesthetic-surgical procedure.

The thermometers used in the research were new and calibrated by their manufacturers and recalibrated every six months, according to the institutional routine. The peripheral digital infrared temporal thermometer (GTech® Model FR1DZ1) had a reading accuracy of ±0.3°C between 34°C and 35.9°C and of ±0.2°C from 36°C to 39°C; the central cutaneous thermometer (Zero-Heat-Flux-Spot On Thermometer 3M®) had a reading accuracy of ±0.2°C between 25°C and 43°C; and the esophageal thermometer (Nihon Kohden®) had a reading accuracy of ±0.1°C between 25°C and 45°C.

Information regarding characterization of the patients was also collected (gender, age, Body Mass Index and surgical risk according to the American Society of Anesthesiologists - ASA classification, among others); specific situations of the anesthetic-surgical procedure and data related to measuring the patients' body temperature were recorded in an instrument created by the authors.

The collecting team comprised two nurses with experience in Intraoperative Nursing assistance and research and four eighth-semester undergraduate students. All data collectors received training to handle the central cutaneous termomethers by the company that supplied the devices. The main researcher provided training for handling the peripheral digital infrared temporal thermometer and filling in the data collection instrument. The data collection team also received a guide about filling out the data collection instrument and other relevant information about the study. Two researcher nurses weekly audited the data collected for completeness and correction.

Statistical analysis

Values are presented as number, percentage, mean, Standard Deviation (SD), minimum and maximum. The Intraclass Correlation Coefficient (ICC) was used to analyze agreement between the measurements obtained by the different thermometers tested, where "1" shows a perfect correlation and "0" a low correlation. Agreement between temperatures was evaluated by means of Bland-Altman analysis. All calculations were performed with the R software program (version 4.1.2; R Foundation for Statistical Computing).

Ethical considerations

Ethical approval was provided by the Ethics Committee under number 3.389.573. Written informed consent was obtained from all participants.

Results

A total of 110 patients who met the inclusion criteria in the immediate preoperative period were approached, of which five did not wish to participate in the research. Of the 105 candidates who accepted, four participants were excluded after acceptance for having undergone a video laparoscopic abdominal surgical procedure and two patients were excluded for not complying with the minimum stipulated surgery time of one hour. Thus, 99 surgical patients were allocated to the study.

A total of 99 patients were analyzed, with predominance of men (55.6%), white-skinned (62.2%), with a mean age of 60.4 years old (SD=13.8), mean Body Mass Index (BMI) of 26.7 kg/m^2 (SD=5.9), who underwent elective abdominal oncologic surgeries with a mean length and anesthesia time of six hours and 17 minutes (SD=2.8 hours) and surgery time of 4.9 hours (SD=2.8 hours), respectively (Table 1). Warming by means of warm forced air was used intraoperatively in all the patients evaluated.

The temperature in the operating room during the intraoperative period averaged 21.0ºC (SD=1.44), with a minimum value of 17.4ºC and a maximum of 24.9ºC. The mean OR humidity was 37.21% (SD=9.43), with a minimum value of 10% and a maximum of 70%.

Table 1 - Demographic and clinical-surgical characteristics of the surgical patients evaluated (n=99). São Paulo, Brazil, 2021

Variables	N=99
Age (years old); mean±SD*	60.44±13.78
Gender; n (%)	
Male	55 (55.56)
Female	44 (44.44)
Body Mass Index (kg/m²); mean±SD*	26.73±5.96
Comorbidities; n (%)	
Hypertension	42 (42.42)
Diabetes *mellitus*	21 (21.21)
Obesity	11 (11.11)
Diagnosis; n (%)	
Digestive tract tumors	51 (51.51)
Urinary tract tumors	29 (29.29)
Reproductive system, pelvis or genital tumors	19 (19.19)
ASA† Classification; n (%)	
ASA† I	2 (2.02)
ASA† II	62 (62.63)
ASA† III	34 (34.34)
ASA† IV	1 (1.01)
Anesthesia; n (%)	
General balanced/IV‡ + Epidural	74 (74.74)
General balanced/IV‡ + Spinal anesthesia	14 (14.14)
General balanced/IV‡ + Transversus abdominis plane block	6 (6.06)
General IV‡ total	5 (5.05)
Surgery performed; n (%)	
Gastrointestinal	49 (49.49)
Urological	27 (27.27)
Gynecological	12 (12.12)
Multiple	11 (11.11)
Surgery time (hours); mean±SD*	4.95±2.78
Anesthesia time (hours); mean±SD*	6.17±2.98

*SD = Standard Deviation; †ASA = American Society of Anesthesiologists; ‡IV = Intravenous

Figure 1 shows the behavior of the temperatures measured intraoperatively by the different devices tested and from the beginning of the surgical procedure; the TT maintains higher measurement values than those identified by the other devices tested.

When comparing the TT and the central measurements, the Intraclass Correlation Coefficient (ICC) of the central cutaneous thermometer was 0.0324 and that of the esophageal/nasopharyngeal thermometer was -0.138, indicating a low correlation between the measurements. The comparison between central thermometers (central cutaneous and esophageal/nasopharyngeal) showed a high correlation (0.744).

The Bland-Altman analysis revealed the same that was observed by the ICC, which is that the peripheral thermometer showed higher temperatures than the central thermometers evaluated (Figures 2 and 3), whereas the invasive measurements indicated greater agreement (Figure 4).

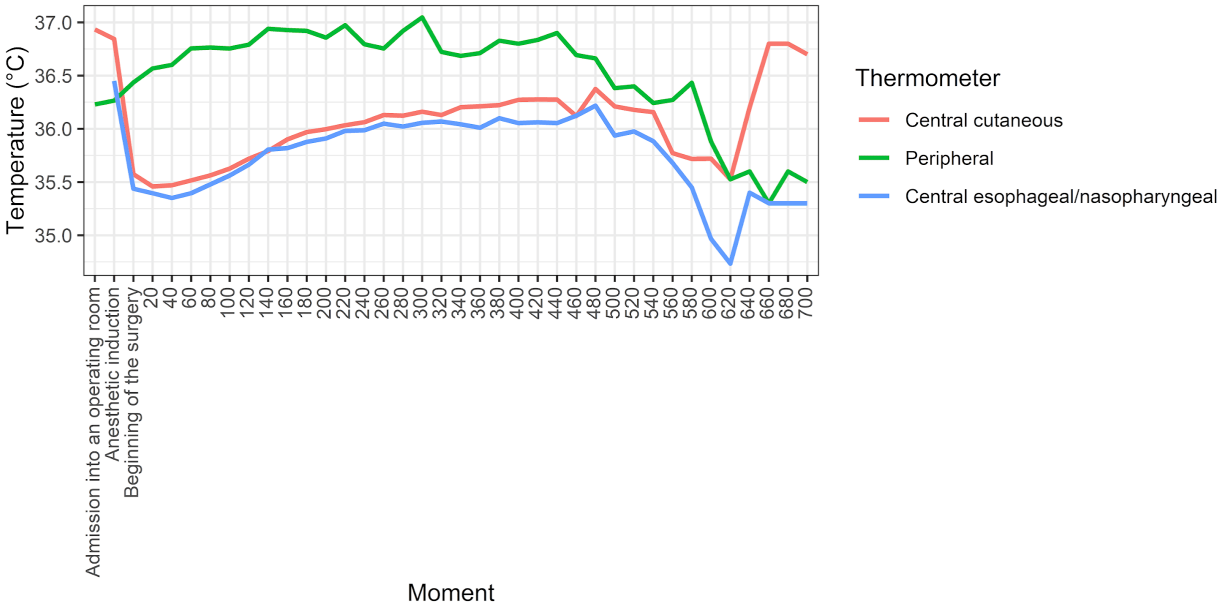

Figure 1 - Correlation between the mean temperatures obtained by central thermometers (central cutaneous and esophageal/nasopharyngeal) and the peripheral (temporal) thermometer among the intraoperative surgical patients (n=99). São Paulo, Brazil, 2021

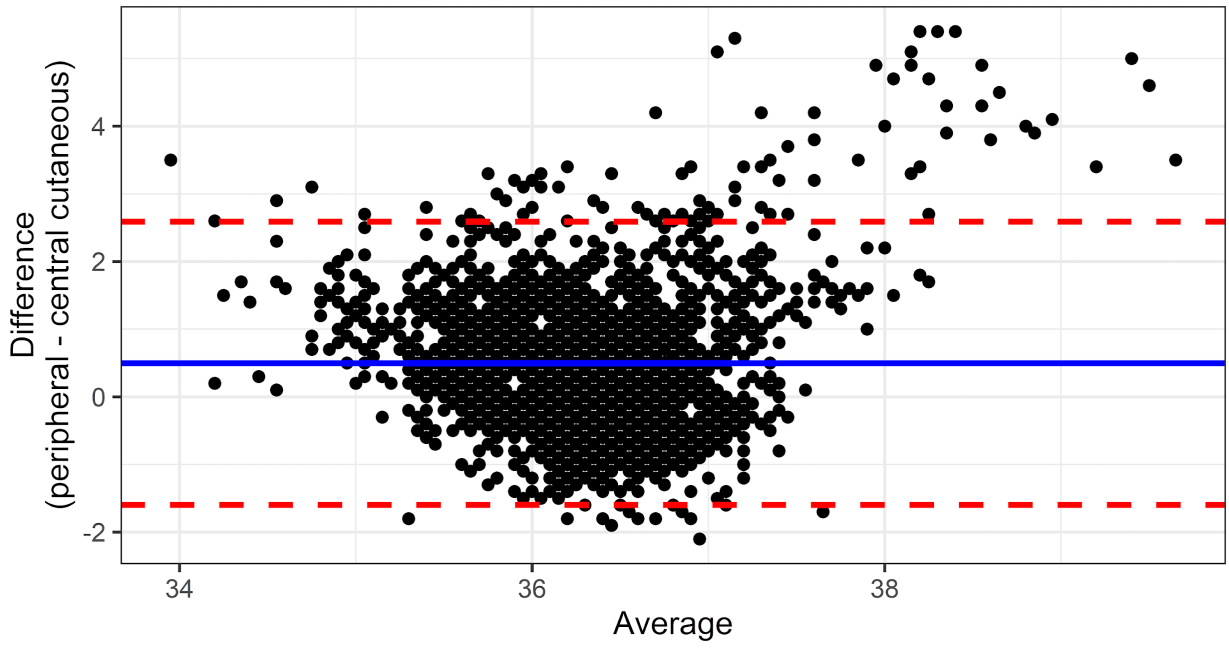

Figure 2 - Bland-Altman plot comparing the peripheral temporal and central cutaneous thermometers. São Paulo, Brazil, 2021

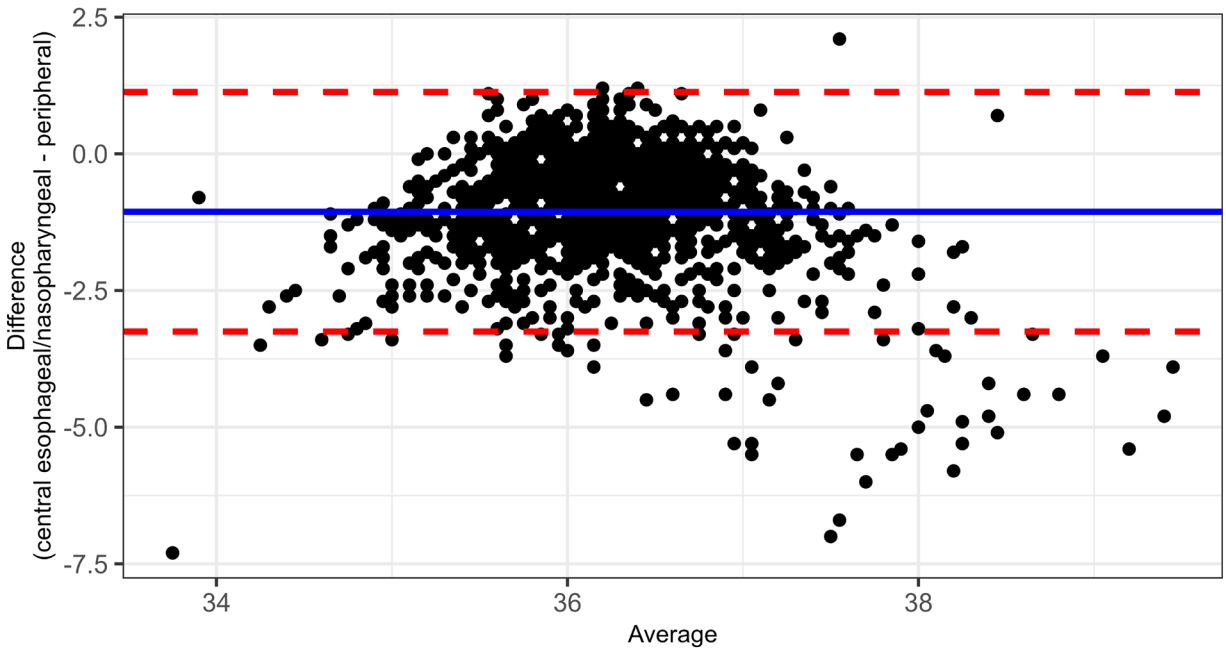

Figure 3 - Bland-Altman plot comparing the peripheral temporal and central esophageal/nasopharyngeal thermometers. São Paulo, Brazil, 2021

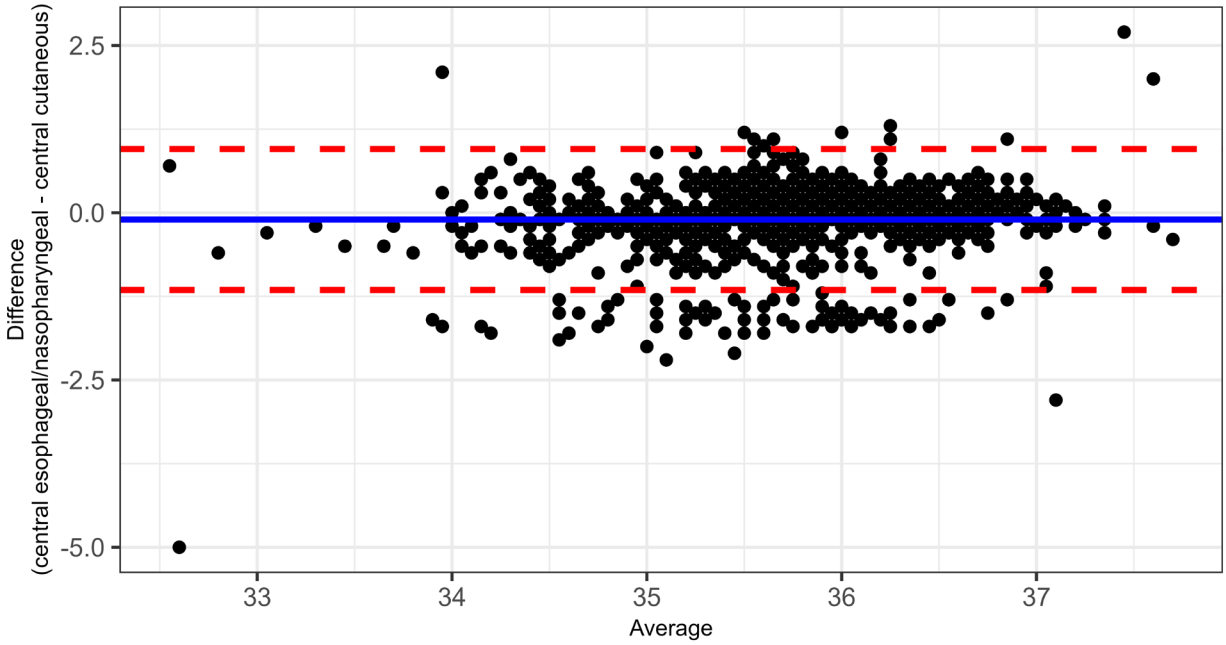

Figure 4 - Bland-Altman plot comparing central cutaneous thermometer and central esophageal/nasopharyngeal thermometer. São Paulo, Brazil, 2021

There was malfunction of the CCT equipment in 8 (8.08%) of the cases, which was solved by changing the adhesive device or reading equipment.

Discussion

The data showed that the peripheral infrared temporal thermometer does not represent reliable temperature measurements when applied to perioperative conditions since, despite its use practicality, the device seems to be more affected by specific intraoperative environmental conditions such as exposure to cooler operating room temperatures or proximity to heat-generating equipment such as cutaneous warming systems.

Furthermore, the TT presented discordance greater than 1.5°C, especially at the beginning of the surgical procedure, appearing to be unreliable for estimating severity of the perioperative hypothermia at the beginning

of the surgery. On the other hand, when analyzing the temperatures measured by the central thermometers evaluated in the current study, the CCT has equivalent temperature measurements to the central temperature measurements estimated by invasive methods, such as the esophageal or nasopharyngeal thermometers. Moreover, both devices can be connected to monitoring systems, allowing automatic and reliable recording of all temperature measurements when there is an integrated electronic medical record system.

Peripheral thermometers generally tend to estimate temperatures lower than central ones, as verified in another study which analyzed the temperature measurement by an infrared Peripheral Tympanic Thermometer (PTT) and observed constantly lower measurements than those obtained by the esophageal thermometer[11]. A similar aspect was also verified in laboratory conditions, where the measures estimated by the TT were inferior to those measured by the PTT[12]. In this sense, the literature indicates that the best temperature estimates among the currently available peripheral thermometers are related to PTTs[11-12].

It is also worth noting that infrared thermometers were oftentimes used under different conditions during the COVID-19 pandemic, with frequent occurrence of false negative checks for fever, meaning that they were unable to correctly detect temperatures equal to or greater than 38°C[12-13].

Nevertheless, due to their practicality, peripheral thermometers might be a valuable tool in other health care settings, as shown in a Japanese study that examined the agreement between the core temperature values and the forehead, tympanic membrane and axillary values during the first four postoperative hours of 65 patients subjected to abdominal surgeries[14]. The authors observed that the readings of the forehead and tympanic thermometers were almost equivalent, although the measures obtained by those devices were inferior when compared to the central measures, although with good equivalence[14].

Regarding the central thermometers, a prospective observational analysis comparing CCT to pulmonary artery catheter, nasopharyngeal, bladder and rectal thermometers measures in 40 patients undergoing off-pump coronary artery bypass surgery or pulmonary thromboendarterectomy showed good agreement between CCT and central pulmonary artery thermometers[15].

Another prospective observational study analyzing postoperative patients in Intensive Care Units (ICUs) comparing non-invasive thermometers such as Double-sensor and CTT to Swan-Ganz catheter temperature measures noticed that both non-invasive methods underestimated the temperature values when compared to the invasive measures, but in a range that is clinical acceptable, and that they might be a good option for detecting hypothermia in ICUs[16].

A systematic review with meta-analysis sought to determine the accuracy and precision of CCTs across 16 studies included, in which quality of the evidence was considered moderate due to concerns about the limitations of the studies, suggesting that the devices may not be appropriate to support clinical decisions where differences of one degree upward or downward is important for determining treatment[17].

Most of the studies conducted analyze the accuracy of CCTs in a surgical environment, where identifying hypothermia is oftentimes more relevant and also more frequent; however, temperature measurement also plays a critical role in determining the most appropriate treatments in different settings such as Emergency departments. Thus, CCTs were compared to other central temperature measurement devices (rectal, bladder and esophagus) and it was found that, despite the equivalence between the measurements of the different thermometers tested among 268 patients, the CCT measures showed decreasing values as the patients' temperature increased, in addition to not being able to detect fever in 25% of the patients evaluated[18].

Another aspect that deserves to be highlighted are the possible problems related to the equipment and disposable device for measuring CCT while the current study was conducted with the need to change the disposable device, which would entail a higher cost for the health service, or even exchanging the reading equipment with another device, which constitutes similar aspects to those observed in a previous survey[19].

Unfortunately, the evidence about cost-benefit analysis regarding thermometers or other perioperative technologies is limited, although the scientific literature agrees that hypothermia prevention reduces major postoperative complications[1-3] that might exert an impact on health care costs. In this sense, an Australian cost-effectiveness analysis of a thermal care bundle to prevent perioperative hypothermia observed that such bundle reduced costs and improved the patients' quality of life, which might indicate that it is a good option for hospitals to allocate additional resources to implement thermal care bundles[20].

Thus, the current study and the evidence found in the literature seem to indicate that there is good accuracy and precision in CCT measurements when compared to other central thermometers, especially when it comes to detecting hypothermia; however, eventual technical problems can economically overload the hospitals. In addition, further studies are suggested evaluating the device in intensive

care and emergency sectors, especially to identify its accuracy in relation to temperature measurements that portray febrile conditions.

This study was limited by the small sample size and the joint analysis of esophageal or nasopharyngeal temperature measurements, as device allocation was determined by the anesthesiologist and the patients' clinical-surgical conditions.

Conclusion

The intraclass correlation coefficient showed a low correlation between the peripheral temporal thermometer and the central cutaneous and esophageal/nasopharyngeal thermometer measurements, and a high correlation (0.744) between the measurements performed with the central thermometers evaluated.

Thus, the data from the current study do not recommend using infrared temporal thermometers as a strategy for measuring the body temperature of patients undergoing anesthetic-surgical procedures during the perioperative period. The two central thermometers tested are equivalent for detecting intraoperative hypothermia, which enables an analysis of the cost-benefit ratio for health services in the use of these devices. Finally, it is believed that this study will enable applying the best scientific evidence related to perioperative temperature measurement to the clinical practice.

Further research studies should be conducted about cost-benefit analysis on the new technologies applied to surgical patients and their sustainability and environmental impact.

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Authors' contribution

Study concept and design: Vanessa de Brito Poveda. **Obtaining data:** Ariane Souza do Nascimento, Cassiane de Santana Lemos, Fernanda Baratojo Biachi, Fernanda Ribeiro Silva de Lyra, Juliana Rizzo Gnatta, Vanessa de Brito Poveda. **Data analysis and interpretation:** Ariane Souza do Nascimento, Cassiane de Santana Lemos, Fernanda Baratojo Biachi, Fernanda Ribeiro Silva de Lyra, Juliana Rizzo Gnatta, Vanessa de Brito Poveda. **Statistical analysis:** Cassiane de Santana Lemos, Juliana Rizzo Gnatta, Vanessa de Brito Poveda. **Drafting the manuscript:** Ariane Souza do Nascimento, Cassiane de Santana Lemos, Fernanda Baratojo Biachi, Fernanda Ribeiro Silva de Lyra, Juliana Rizzo Gnatta, Vanessa de Brito Poveda. **Critical review of the manuscript as to its relevant intellectual content:** Ariane Souza do Nascimento, Cassiane de Santana Lemos, Fernanda Baratojo Biachi, Fernanda Ribeiro Silva de Lyra, Juliana Rizzo Gnatta, Vanessa de Brito Poveda.

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