

Comparison between forced-air and air-free warming on perioperative hypothermia in patients undergoing elective surgery

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To the Editor: Hypothermia is described as a state in which the core temperature of a patient is decreased to equal to or $<36^{\circ}$, which is a common and severe complication among patients undergoing elective surgery.^[1] Studies reported that hypothermia is associated with an increased risk of several adverse events including postoperative shivering, surgical site infection, increased blood loss, and a longer length of hospitalization.^[2] Active warming for >30 min during the surgical procedure has been found to reduce the risk of perioperative hypothermia. Thus, more and more attention has been paid to how effectively prevent perioperative hypothermia, and many intraoperative active warming strategies have therefore been applied in clinical practice, such as forced-air warming technology, prewarming technology before anesthesia, resistive-polymer system, circulating water mattresses, and self-warming blanket.

Among those warming strategies, forced-air warming is extensively used to prevent perioperative hypothermia among patients undergoing surgery.^[3] Unfortunately, convective warming system has been demonstrated to increase the risk of surgical site infection because it disrupts unidirectional laminar airflow. More importantly, pathogenic organisms have been detected from the hose of forced-air warming devices.^[4]

Compared with convective warming systems, conductive warming systems have no noticeable impact on unidirectional laminar airflow (ie, ventilation from ceiling to floor) in the operation room.^[5] Nevertheless, the comparative efficacy and safety between convective warming (eg, forced-air warming) and conductive warming (eg, air-free warming) in preventing postoperative hypothermia, surgical site infection, and other clinical outcomes have not yet been systematically investigated among patients undergoing elective surgery. Therefore, this meta-analysis

was conducted to objectively examine the comparative efficacy and safety of forced-air and air-free warming systems among patients undergoing selective surgery.

This systematic review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guideline. Two independent reviewers searched PubMed, EMBASE, and the Cochrane Library to capture all potential randomized controlled trials (RCTs) from their inception through December 2020 using the following terms, including "hypothermia," "forced-air warming," and "random". We also applied hand-search to obtain any missed studies from electronic search. As an example, we summarized the search strategy of PubMed in Supplementary Table 1, <http://links.lww.com/CM9/B49>. Eligible studies were selected according to the following five inclusion criteria: (a) all of the patients undergoing elective surgery, irrespective of anesthesia approach; (b) the comparison of forced-air warming and air-free warming was investigated; (c) only RCT was considered to be eligible; (d) at least one of the following outcomes, including hypothermia, postoperative core temperature, surgical site infection, shivering, and thermal comfort, was reported; and (e) only RCT published in English language and with a sample size of >40 patients was considered. Studies were excluded according to: (a) ineligible study design including reviews, letters, abstracts, editorials, or studies reporting insufficient data; (b) duplicate study with insufficient data; and (c) no control group. Two independent reviewers extracted essential data. We used estimation formulas to estimate the mean and standard deviation if the outcomes were expressed as median, range, or interquartile range.^[6] Hypothermia and postoperative core temperature were regarded as the primary outcomes, and the incidence of surgical site infection and shivering and thermal comfort was regarded as the second outcomes. The methodological quality of the individual

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study was assessed by using the Cochrane risk of bias assessment tool. Any disagreement about data extraction between the reviewers was solved by consulting a third senior reviewer. Statistical analyses were conducted using Review Manager 5.3 (The Nordic Cochrane Centre, the Cochrane Collaboration, Copenhagen, 2014).

Twenty-five RCTs (Supplementary Table 2, <http://links.lww.com/CM9/B49>) involving 2265 patients undergoing elective surgery were included for the final analysis, and the sample size of the individual study ranged from 40 to 246, with a median of 70. The process of studies retrieval and selection is shown in Supplementary Figure 1, <http://>

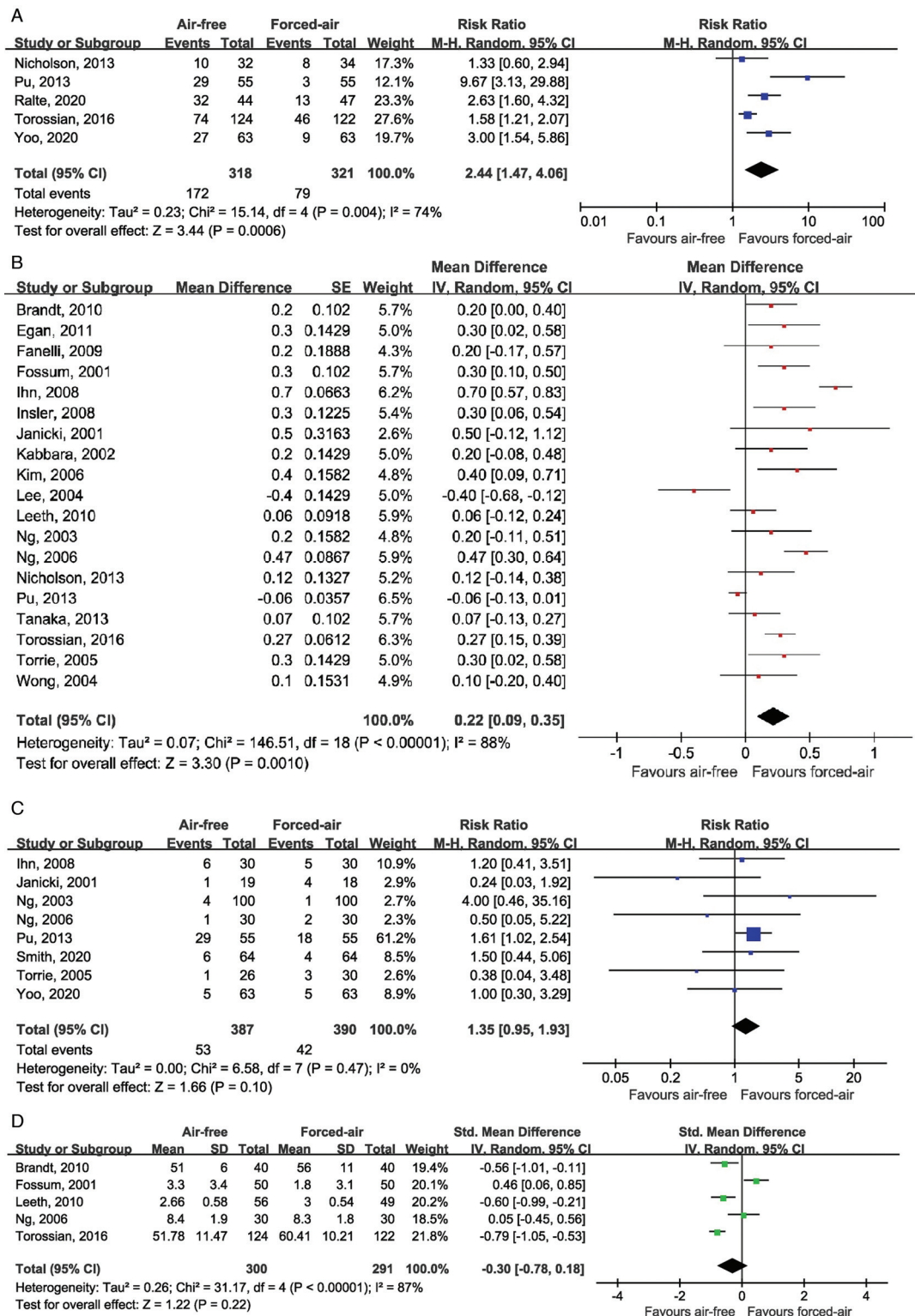


Figure 1: Forest plot of meta-analysis of hypothermia (A), postoperative core temperature (B), shivering (C), and thermal comfort (D) between forced-air and air-free warming systems.

links.lww.com/CM9/B49, and the basic characteristics of all included studies are summarized in Supplementary Table 3, <http://links.lww.com/CM9/B49>. All studies reported to randomly assign eligible patients into independent groups, however, only 19 studies clearly described the methods of generating random sequence, and 19 eligible studies appropriately concealed random sequence. Two studies did not blind participants and personnel and one study did not blind outcome assessors. Six studies missed data but it did not use an appropriate statistical method to address this bias. For the remaining items, all studies were considered as low risk of bias (Supplementary Table 4, <http://links.lww.com/CM9/B49>).

The pooled result suggested that, compared to air-free warming systems, forced-air warming system significantly reduced the incidence of hypothermia (5 RCTs; risk ratio [RR], 2.44; 95% confidence interval [CI], 1.47–4.06; $P < 0.001$), increased postoperative core temperature (19 studies; mean difference, 0.22; 95% CI, 0.09–0.35; $P = 0.001$), and reduced the incidence of postoperative shivering although the difference between the two groups did not achieve statistical significance (8 studies; RR, 1.35; 95% CI, 0.95–1.93; $P = 0.10$). The pooled result also revealed a comparable efficacy between both warming systems in thermal comfort (5 studies; standard mean difference, -0.30 ; 95% CI, -0.78 – -0.18 ; $P = 0.22$), which was supported by qualitative results. The pooled result was shown in Figure 1. Moreover, qualitative analysis suggested no statistical difference between both warming systems in surgical site infection during a surgical procedure. The symmetrical funnel plot indicated no publication bias for postoperative core temperature (Supplementary Figure 2, <http://links.lww.com/CM9/B49>).

The current systematic review investigated the comparative efficacy and safety between forced-air and air-free warming systems among patients undergoing elective surgery, and findings suggested that forced-air warming reduced the incidence of hypothermia and accelerated the recovery of postoperative core temperature, however, no statistical difference was detected in terms of incidence of surgical site infection and shivering and thermal comfort between two systems.

To date, Liu *et al*^[7] conducted a meta-analysis to investigate the comparative efficacy and safety between forced-air and air-free warming systems in preventing perioperative hypothermia among patients receiving total hip and knee arthroplasty, and found no statistical difference in postoperative temperature, postoperative core temperatures, thermal comfort, the incidence of shivering, and hypothermia between the air-free warming and forced-air warming systems. However, the current systematic review found that forced-air warming effectively decreased the incidence of hypothermia and accelerated the recovery of postoperative core temperature although no statistical difference in the incidence of surgical site infection and postoperative shivering and thermal comfort. Compared to the previous meta-analysis, our systematic review focused on general surgical patients rather than specific surgical patients, and thus the generalization of our findings was better. Meanwhile, we also included surgical site infection as an outcome of interest in

order to objectively evaluate the comparative safety between the two systems. Moreover, we only considered those studies with a total sample size of >40 patients to meet our inclusion criteria because of inadequate sample size has a higher risk of generating biased results. More importantly, we also utilized qualitative results to supplement the strength of the quantitative result of thermal comfort.

Our meta-analysis has some limitations. First, the aim of our systematic review is to inveterate comparative efficacy and safety of two warming systems in patients undergoing various elective surgeries and thus significant heterogeneity cannot be avoided. However, as a result, our findings can be popularized to broader surgical patients in clinical practice. Second, various types of anesthesia were applied in patients, however, we did not perform subgroup analyses to examine the robustness of pooled results due to an inadequate number of accumulated eligible for most outcomes. Third, various temperature settings were reported in various studies, which might have a different effect on the efficacy of warming. Fourth, we did not generate a funnel plot to examine the possibility of publication bias for most outcomes due to the limited number of accumulated studies. Fifth, our analysis was unable to draw a conclusion regarding surgical site infection, which is an important outcome of evaluating the comparative safety of forced-air and air-free warming systems.

In conclusion, our systematic review demonstrates that a forced-air warming system is superior to air-free warming system because it effectively decreases the incidence of hypothermia and accelerates the recovery of postoperative core temperature in patients undergoing elective surgery. However, large-scale studies with high quality are needed to further investigate the role of two warming systems in causing surgical site infection and postoperative shivering and improving thermal comfort.

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