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REVIEW

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Optimal temperature management in aortic arch surgery: A systematic review and network meta-analysis

Djamila Abjigitova MD[1] | Maximiliaan L. Notenboom BSc[1] | Kevin M. Veen MD, PhD[1] | Gabriëlle van Tussenbroek BSc[1] | Jos A. Bekkers MD, PhD[1] | Mostafa M. Mokhles MD, PhD[2] | Ad J. J. C. Bogers MD, PhD[1]

[1]Department of Cardiothoracic Surgery, Erasmus University Medical Center, Rotterdam, The Netherlands

[2]Department of Cardiothoracic Surgery, Utrecht University Medical Center, Utrecht, The Netherlands

Correspondence
Djamila Abjigitova, MD, Department of Cardiothoracic Surgery, Erasmus University Medical Center, Room Rg-619, PO Box 2040, 3000 CA Rotterdam, the Netherlands.
Email: d.abjigitova@erasmusmc.nl

Abstract

Objectives: New temperature management concepts of moderate and mild hypothermic circulatory arrest during aortic arch surgery have gained weight over profound cooling. Comparisons of all temperature levels have rarely been performed. We performed direct and indirect comparisons of deep hypothermic circulatory arrest (DHCA) (≤20°C), moderate hypothermic circulatory arrest (MHCA) (20.1–25°C), and mild hypothermic circulatory arrest (mild HCA) (≥25.1°C) in a network meta-analysis.

Methods: The literature was systematically searched for all papers published through February 2022 reporting on clinical outcomes after aortic arch surgery utilizing DHCA, MHCA and mild HCA. The primary outcome was operative mortality. The secondary outcomes were postoperative stroke and acute kidney failure (AKI).

Results: A total of 34 studies were included, with a total of 12,370 patients. DHCA was associated with significantly higher postoperative incidence of stroke when compared with MHCA (odds ratio [OR], 1.46, 95% confidence interval [CI], 1.19–1.78) and mild HCA: (OR, 1.50, 95% CI, 1.14–1.98). Furthermore, DHCA and MHCA were associated with higher operative mortality when compared with mild HCA (OR 1.71, 95% CI, 1.23–2.39 and OR 1.50, 95% CI, 1.12–2.00, respectively). Separate analysis of randomized and propensity score matched studies showed sustained increased risk of stroke with DHCA in contrast to MHCA and mild HCA (OR, 1.61, 95% CI, 1.18–2.20, *p* value = .0029 and OR, 1.74, 95% CI, 1.09–2.77, *p* value = .019).

Conclusions: In the included studies, the moderate to mild hypothermia strategies were associated with decreased operative mortality and the risk of postoperative stroke. Large-scale prospective studies are warranted to further explore appropriate temperature management for the treatment of aortic arch pathologies.

KEYWORDS

aortic arch surgery, cerebral perfusion, deep hypothermic circulatory arrest, hypothermia, mild, moderate, network meta-analysis

1 | INTRODUCTION

Different hypothermia regimens alone or combined with selective cerebral perfusion can be used for cerebral protection during surgical interventions involving the aortic arch. Historically, cooling of the brain to profoundly hypothermic levels seemed safe. However, transitions to warmer hypothermic temperatures in conjunction with antegrade cerebral perfusion has become the trend in the last decades.[1–3] Despite favorable clinical results reported with newer techniques, a variation in hypothermia regimes persists to exist between centers worldwide.

Evidence on outcome differences between the proposed techniques and different levels of hypothermia during aortic arch surgery is scattered across many publications. Over the last decades, several meta-analyses have compared different levels of hypothermia in different combinations in a pairwise fashion.[4–7] However, no meta-analysis has compared all three levels of hypothermia, deep, moderate and mild.

Network meta-analysis (NMA) allows comparisons between more than two treatment arms. The advantage of network meta-analysis is that it facilitates indirect comparisons of multiple interventions that have not been studied in a head-to-head fashion.[8] Hence we have used a network meta-analysis approach to compare the effect of deep hypothermic circulatory arrest (DHCA), moderate hypothermic circulatory arrest (MHCA) and mild hypothermic circulatory arrest (mild HCA) on the operative mortality, postoperative occurrence of stroke and acute kidney renal failure (AKI) after aortic arch surgery.

2 | METHODS

2.1 | Protocol and registration

This systematic review was performed according to the checklist of the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) extension statement for network meta-analysis [9] and registered with PROSPERO (International Prospective Register of Systematic Reviews, CRD42021246372). This study was approved by the institutional review board (MEC-2019-0825).

2.2 | Search strategy and selection criteria

A biomedical information specialist performed a comprehensive search on February 21, 2022 in Embase, Medline, Web of Science, Cochrane, and Google Scholar databases (search terms are available in Supporting Information). Two researchers (D. A. and G. T.) independently reviewed abstracts and full texts based on predefined inclusion/exclusion criteria. Observational studies, both retrospective and prospective, and randomized controlled trials (RCTs) that reported outcomes after aortic arch surgery in adults with a sample size ≥10 patients, published in English, were included. Non-original studies (reviews), case reports, poster publications, conference presentations, animal studies, editorials, studies not defining or incomplete reporting of outcome and data were excluded. Studies had to compare at least two study arms to be eligible for inclusion in the network meta-analysis. Furthermore, studies reporting on hybrid aortic arch procedures, other than frozen elephant trunk, solely redo cases, type B aortic dissections, articles on exclusively concomitant procedures, mini-sternotomy and all different approaches other than median sternotomy were excluded. In case of disagreement, an agreement was negotiated until consensus was reached. In case of multiple publications on overlapping study populations, the largest series were included.

2.3 | Data extraction

Microsoft Office Excel 2016 (Microsoft Corp) was used for data extraction. Two reviewers (D.A. and G.T.) independently extracted the data and recorded all data with a standardized form. All two-arm (two groups reported) studies with a within-study comparison of different hypothermia regimens, regardless of cerebral perfusion strategy, were extracted. The different levels of hypothermia were classified as following: deep hypothermia (≤20°C), moderate hypothermia (20.1°C to 25°C), mild hypothermia (≥ 25.1°C). The cutoff of 20°C to separate the patients into moderate versus deep hypothermia cohorts was consistent with the International Aortic Arch Surgery Study Group (IAASSG) consensus guideline regarding the nomenclature of hypothermia during aortic arch surgery.[10] In the literature, moderate hypothermia is often referred to as low-MHCA, while mild hypothermia is often considered high-MHCA. Concerning the location of temperature measurement, the rectal temperature was reported in almost all studies. If no rectal temperature was present in a publication, the nasopharyngeal temperature was reported. Outcomes were considered early outcomes when they occurred within 30 days postoperatively or during the period of initial hospital admission. Extracted baseline characteristics and outcome measures are provided in Supporting Information: Table S1.

2.4 | Assessment of the quality of individual studies and overall quality of evidence

In the studies with a within-study comparison of the hypothermia regimens, the Newcastle-Ottawa quality assessment scale was used to assess bias in observational studies.[11] In case of a randomized controlled trial, the Cochrane risk of bias tool was used.[12]

2.5 | Outcome measures

The primary outcome was operative mortality. Secondary outcomes were postoperative incidence of stroke and AKI.

2.6 | Statistical analysis

Sample-sized weighted pooled baseline patient and procedural characteristics were calculated for each hypothermia regimen group. Early event risks were pooled using inverse variance weighting and pooled in a random-effects model using the Der Simonian and Laird method to estimate the between-study variance.[13] Random-effect meta-analysis was performed using 'metafor' and 'meta' packages in R (version 4.0.5., R Project for Statistical Computing).

2.6.1 | Network meta-analysis

Odds ratios (ORs) were used for the early outcome and were calculated by extracting the raw data from the studies. NMA was performed using the frequentist method (generic inverse variance method) with the 'netmeta' statistical package in R (version 4.0.5., R Project for Statistical Computing), as described by Rücker et al.[14] Random effect network meta-analyses were performed to make direct and indirect comparisons of two- and three-arm studies comparing different levels of hypothermia in aortic arch surgery.[15] Inconsistency in NMA was evaluated by conducting conventional pairwise meta-analyses and comparing direct and indirect OR, also called node-splitting. Additionally, quadratic net heat plots were computed to investigate inconsistency. Heterogeneity was reported as low (I^2 = 0–25%), moderate (I^2 = 26–50%), or high (I^2 > 50%).

2.6.2 | Sensitivity analyses

To minimize possible confounding that can be encountered in observational research, data from randomized controlled trials (RCTs) and propensity score matched (PSM) studies were analyzed separately.

3 | RESULTS

The literature search resulted in a total of 6429 publications. After the removal of duplicates, 2483 articles remained, of which 34 met the inclusion criteria and were included in the final network meta-analysis (Figure 1). Included were two RCTs and 32 observational of which nine were PSM. The assessment of the quality of the individual studies and the evidence is reported in Supporting Information: Tables S1 and S3.

3.1 | Study and patient characteristics and clinical outcome

Individual study characteristics are presented in Supporting Information: Table S4. Ten studies were from United States, six from Japan, four from China, two from Canada, United Kingdom, France, Greece and Germany, one from Austria, Korea, Russia and Saudi Arabia. References of the studies included in this meta-analysis are available in the Online Data Supplement. A total of 12370 patients were included in the final analysis. Pooled patient and procedural characteristics are presented in Table 1. The mean age was 60.4 years in the DHCA group, 59.5 years in the MHCA group and 60.8 years in the mild HCA group. Acute aortic dissections were mainly operated under mild HCA (67.4%), whereas degenerative aneurysms under DHCA (41.5%). The mean lowest rectal temperature was 18.7°C in the DHCA group, 24.0°C in the MHCA group and 28.0°C in the mild HCA group. Mild hypothermia was always used in conjunction with selective cerebral perfusion, most commonly unilateral antegrade cerebral perfusion (88.4%). Retrograde cerebral perfusion (RCP) was mainly utilized in the presence of deep hypothermia (40.2%) (Table 1). Hemiarch surgery was largely done under DHCA (83.1%), whereas total aortic arch surgery was done under moderate HCA (21.4%).

Patients operated under mild hypothermia levels experienced shorter cardiopulmonary bypass (CPB) and aortic cross clamp (ACC) times. Pooled clinical outcome measures for different hypothermia levels are presented in Table 2. Heterogeneity was high in all outcome measures.

3.2 | Pairwise meta-analysis

Detailed results of the pairwise comparisons (DHCA vs. Mild HCA, DHCA vs. MHCA, MHCA vs. Mild HCA) are reported in Figures 2–4. Compared with mild HCA, DHCA and moderate HCA were associated with significantly higher postoperative mortality (odds ratio (OR), 1.92, 95% CI, 1.20–3.07 and OR, 1.41, 95% CI, 1.04–1.92, respectively). Furthermore DHCA was associated with higher postoperative incidence of stroke, when compared with mild and moderate HCA (OR, 1.47, 95% CI, 1.04–2.08, and OR, 1.49, 95% CI, 1.21–1.83, respectively).

3.3 | Network meta-analysis

The network graph illustrates that the most common comparison performed in our network analysis was between DHCA and MHCA (Figure 5).

Differences found in the pairwise comparisons sustained their significance in the network meta-analysis. The use of DHCA and MHCA were associated with significantly higher operative mortality compared with the use of mild HCA (OR, 1.71, 95% CI 1.23–2.39, p value = .0014 and OR, 1.50, 95% CI 1.12–2.00, p value = .007, respectively). Utilization of DHCA was associated with a higher incidence of postoperative stroke compared with the use of MHCA (OR, 1.46, 95% CI, 1.19–1.78, p < .001) and mild HCA (OR, 1.50, 95% CI, 1.14–1.98, p value = .004).

No difference in the postoperative incidence of AKI was found between the different hypothermia levels (Figure 5).

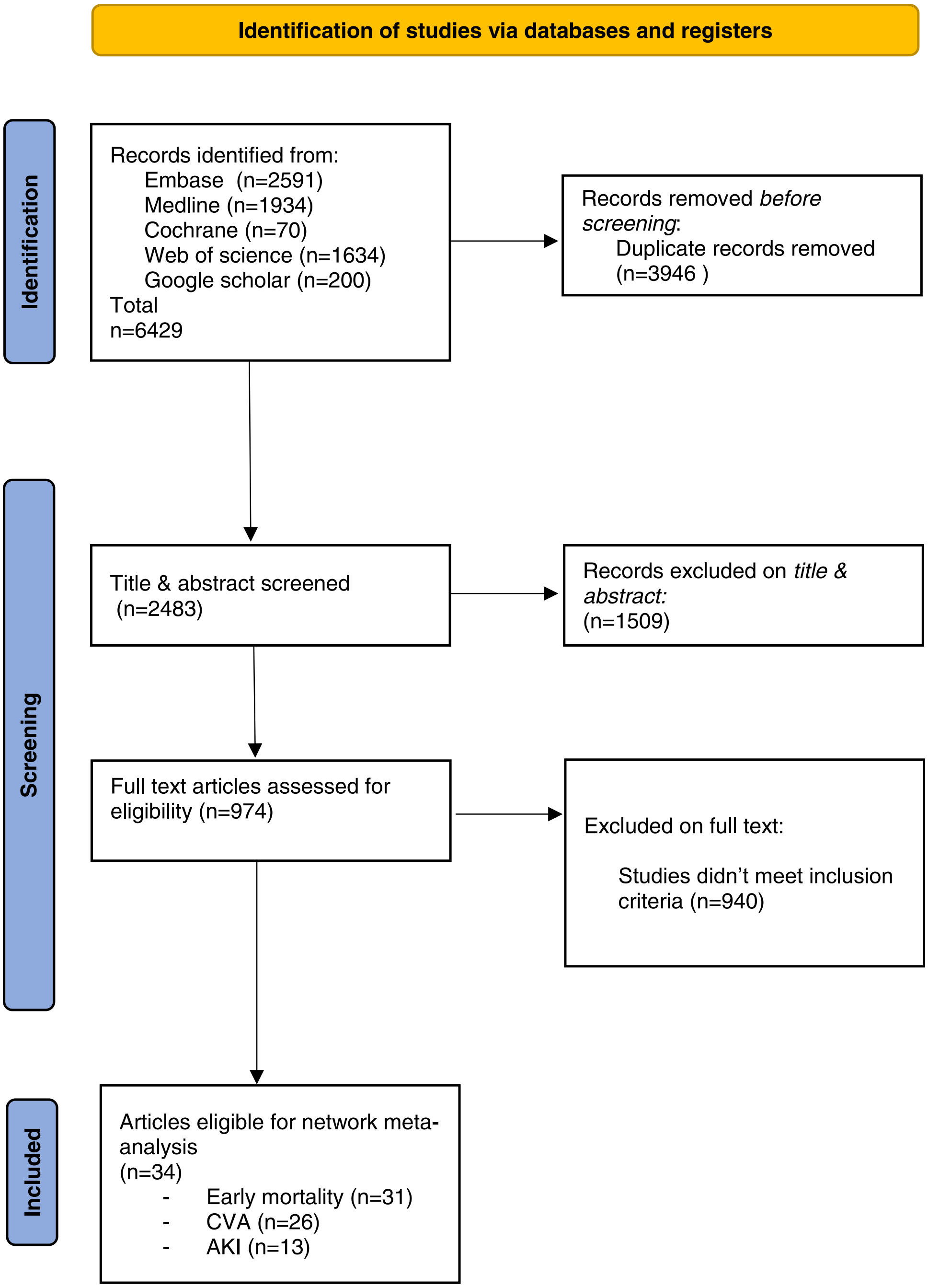

FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart of the analysis

Indirect and direct estimates did not differ significantly, as it's shown in overlapping confidence intervals in netsplit plots (Figures 2–4). Differences between effect estimates based on direct versus indirect evidence were not significant. Inconsistency was not significant for operative mortality ($p = .21$), stroke ($p = .55$), and AKI ($p = .20$). Quadratic net heat plots explored inconsistency of indirect and direct comparisons in network meta-analysis (Supporting Information: Figures S1–S3). The net heat plot for outcome AKI showed relatively higher inconsistency between the different comparisons compared with other outcome measures (Supporting Information: Figure S3). Heterogeneity within direct estimates was low for all outcome measures ($I^2 = 0\%–19.7\%$).

3.4 | RCTs and PSM studies sensitivity analysis

Two RCTs and seven PSM studies included 5425 patients. Baseline characteristics of the included studies are detailed in Supporting Information: Table 5.

TABLE 1 Baseline characteristics

Characteristic	DHCA (<20) Pooled estimate	N	MHCA (20–25) Pooled estimate	N	Mild HCA (>25) Pooled estimate	N
Age (mean ± SD)	60.4 ± 11.8	26	59.5 ± 12.9	33	60.8 ± 12.4	10
Male	65.9% (30.2–88.0)	26	68.4% (40.0–88.9)	30	68.2% (51.6–81.8)	9
Etiology						
ATAAD	52.8% (0.0–100.0)	23	56.6% (0.0–100.0)	31	67.4% (19.9–100.0)	9
Chronic TAAD	2.7% (0.0–100.0)	24	3.4% (0.0–100.0)	31	0.0% (0.0–0.0)	9
Degenerative	41.5% (0.0–100.0)	23	37.4% (0.0–100.0)	31	32.5% (0.0–80.1)	9
Other	2.7% (0.0–45.7)	22	2.7% (0.0–48.6)	31	0.0% (0.0–0.0)	9
Comorbidities						
Hypertension	72.1% (20.0–88.7)	16	72.6% (21.1–85.1)	21	74.5% (17.7–89.8)	6
Emergency	34.8% (0.0–100.0)	9	42.4% (0.0–100.0)	13	37.7% (23.5–100.0)	5
History of CVA	7.6% (2.3–18.5)	16	7.8% (2.7–13.2)	21	5.0% (0.0–13.3)	6
Marfan	4.2% (0.0–14.3)	11	5.4% (0.0–11.5)	15	4.1% (0.0–10.8)	4
COPD	13.3% (0.0–42.0)	12	15.2% (0.0–37.1)	17	17.2% (0.3–34.3)	6
Prev. cardiac surgery	17.7% (0.0–42.2)	19	20.2% (0.0–43.1)	23	21.0% (3.4–42.8)	5
CAD	14.1% (4.4–36.2)	9	13.7% (0.0–35.9)	15	11.2% (2.4–39.2)	6
DM	9.2% (1.1–32.0)	14	9.2% (2.9–27.8)	18	11.3% (2.9–13.3)	5
Cerebral perfusion						
No cerebral perfusion	25.4% (0.0–100.0)	23	8.5% (0.0–100.0)	30	0.0% (0.0–0.0)	9
Unilateral ACP	28.8% (0.0–100.0)	23	45.5% (0.0–100.0)	30	88.4% (0.0–100.0)	9
Bilateral ACP	5.5% (0.0–100.0)	23	21.4% (0.0–100.0)	30	9.6% (0.0–100.0)	9
RCP	40.2% (0.0–100.0)	23	24.5% (0.0–100.0)	30	2.0% (0.0–100.0)	9
Operative details						
Concomitant CABG	12.0% (3.4–36.5)	18	13.3% (2.8–35.0)	25	11.4% (2.7–26.1)	8
Hemiarch replacement	83.1% (0.0–100.0)	20	77.5% (0.0–100.0)	27	79.7% (0.0–100.0)	10
Total arch replacement	15.2% (0.0–100.0)	22	21.4% (0.0–100.0)	30	20.3% (0.0–100.0)	10
Root replacement	25.8% (5.0–88.0)	20	28.6% (2.4–81.4)	26	14.4% (3.2–47.3)	9
AVR	34.8% (5.8–70.2)	14	42.4% (1.9–87.1)	18	59.9% (5.4–75.3)	6
ET	1.9% (0.0–17.3)	24	1.4% (0.0–19.5)	30	2.6% (0.0–28.1)	8
FET	0.0% (0.0–0.0)	21	11.2% (0.0–95.0)	28	25.0% (0.0–82.5)	9
Lowest rectal temp.[a]	18.7 ± 2.2	19	24.0 ± 6.6	23	28.0 ± 1.4	8
Intraoperative outcome						
CPB time (min) (SD)	195.3 (61.6)	25	186.3 (55.8)	32	156.3 (55.0)	10
ACC time (min) (SD)	124.9 (44.8)	22	125.6 (49.9)	28	111.5 (52.6)	7
HCA time (min) (SD)	27.5 (13.9)	21	27.9 (12.8)	25	21.2 (11.9)	8
ACP time (min) (SD)	37.4 (18.7)	6	48.6 (21.8)	10	49.0 (28.1)	4
RCP time (min) (SD)	29.0 (13.0)	1	25.0 (9.7)	1	2.6 (4.3)	1

Note: All values are presented as % (range).

Abbreviations: ACP, antegrade cerebral perfusion; ACC, aortic cross clamp; CABG, coronary artery bypass grafting; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disorder; CPB, cardiopulmonary bypass; CVA, cerebrovascular accident; DHCA, deep hypothermic circulatory arrest; DM, diabetes mellitus; HCA, hypothermic circulatory arrest; ET, elephant trunk; FET, frozen elephant trunk; MHCA, moderate hypothermic circulatory arrest; RCP, retrograde cerebral perfusion; SD, standard deviation.

[a]If no rectal temperature was provided, the mean lowest nasal temperature was used ($n = 7$ for DHCA, $n = 8$ for MHCA, $n = 0$ for mild HCA), presented in degrees Celsius.

TABLE 2 In-hospital outcomes associated with the use of different temperature strategies

Characteristic	DHCA (<20)		MHCA (20–25)		Mild HCA (>25)	
	Pooled estimate (95% CI)	Number of studies (I^2)	Pooled estimate (95% CI)	Number of studies (I^2)	Pooled estimate (95% CI)	Number of studies (I^2)
Operative mortality	9.9 (7.1–13.7)	25 (88.5%)	8.4 (6.1–11.6)	31 (87.5%)	5.7 (3.4–9.4)	9 (85.1%)
Postoperative stroke	8.5 (5.7–12.4)	24 (90.7%)	5.8 (4.3–7.6)	31 (75.6%)	4.9 (3.2–7.6)	10 (74.2%)
Postoperative AKI	15.3 (8.1–27.1)	14 (97.4%)	13.3 (7.8–24.3)	15 (97.0%)	10.3 (1.5–46.1)	2 (91.0%)

Abbreviations: AKI, acute kidney injury; CI, confidence interval; CVA, cerebrovascular accident; DHCA, deep hypothermic circulatory arrest; HCA, hypothermic circulatory arrest; MHCA, moderate hypothermic circulatory arrest.

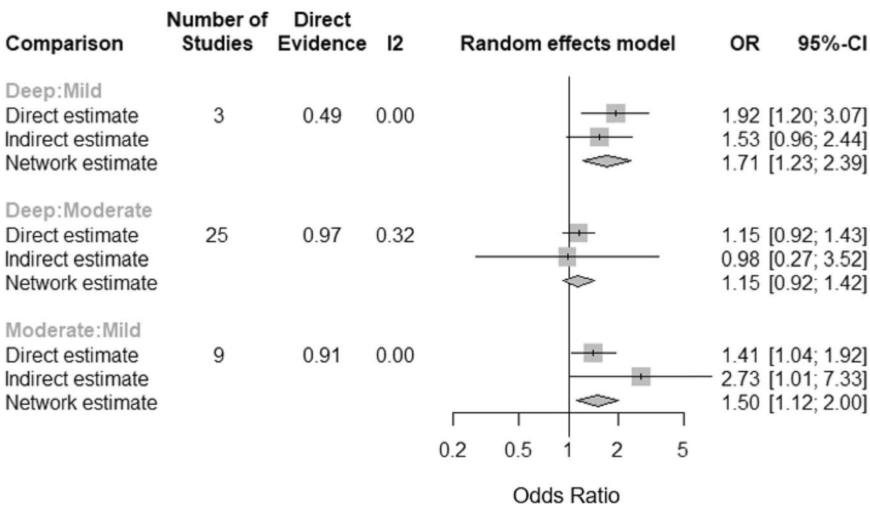

FIGURE 2 Forest plot of net split results of direct, indirect evidence and network estimates for operative mortality

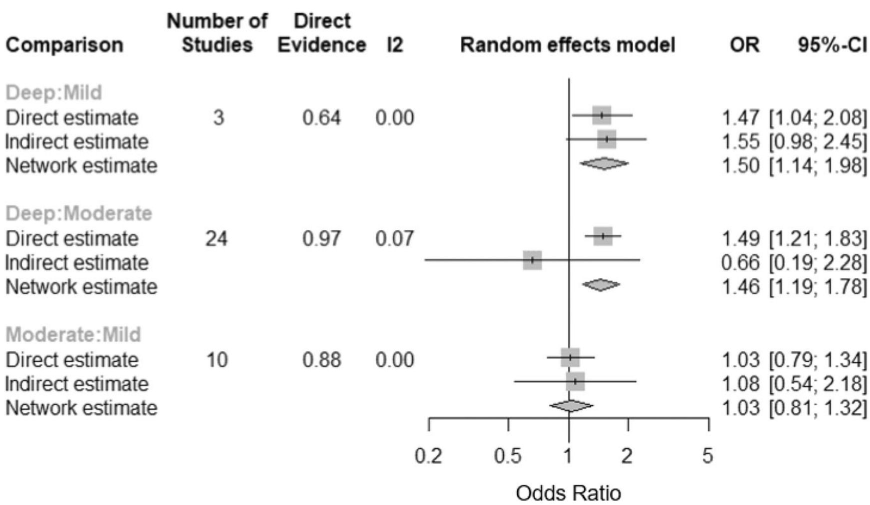

FIGURE 3 Forest plot of net split results of direct, indirect evidence and network estimates for the postoperative incidence of stroke.

The network graph is displayed in Supporting Information: Figure S4. Combining strictly RCTs and PSM studies resulted in sustained significant higher risk of operative mortality for MHCA when compared with mild HCA (OR, 1.45, 95% CI, 1.05–2.00, *p* value = .029) (Supporting Information: Figure S5). Furthermore, sensitivity analysis confirmed significant higher risk of postoperative stroke for DHCA when compared with MHCA and mild HCA (OR, 1.61, 95% CI, 1.18–2.20, *p* value = .0029 and OR, 1.74, 95% CI, 1.09–2.77, *p* value = .019) (Figure 6). No difference in postoperative AKI among different levels of hypothermia was found (Supporting Information: Figure S6). Indirect and direct estimates did not differ significantly, with low inconsistency (Figure 6, Supporting Information: Figure S5 and S6). Differences between effect estimates based on direct evidence were not significant. Heterogeneity/inconsistency were not significant for operative mortality($p = .72$), stroke ($p = .47$) and AKI ($p = .45$). Quadratic net heat plots for outcomes postoperative stroke and mortality are presented in Supporting Information: Figures S7 and S8. Heterogeneity was low for all outcome measures ($I^2 = 0\%$).

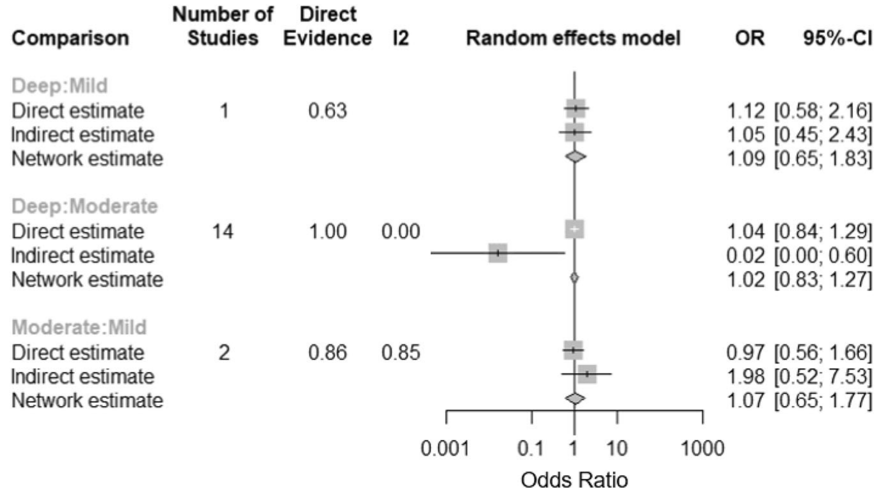

FIGURE 4 Forest plot of net split results of direct, indirect evidence and network estimates for the postoperative incidence of acute kidney insufficiency.

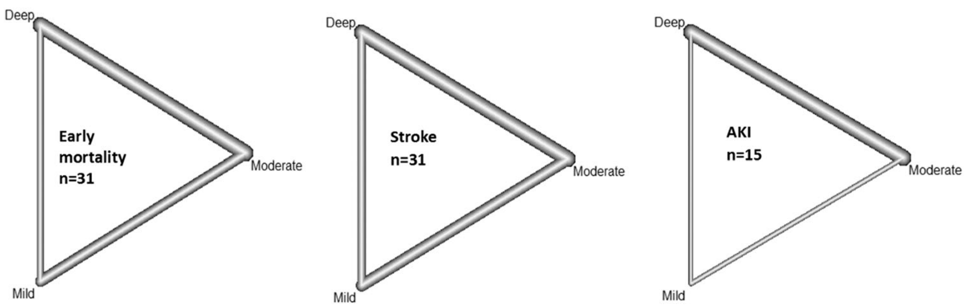

FIGURE 5 Network graphs for all comparisons of the reported outcomes. The thickness of the beams indicates how commonly a comparison was found in the network analysis, in relation to the other comparisons.

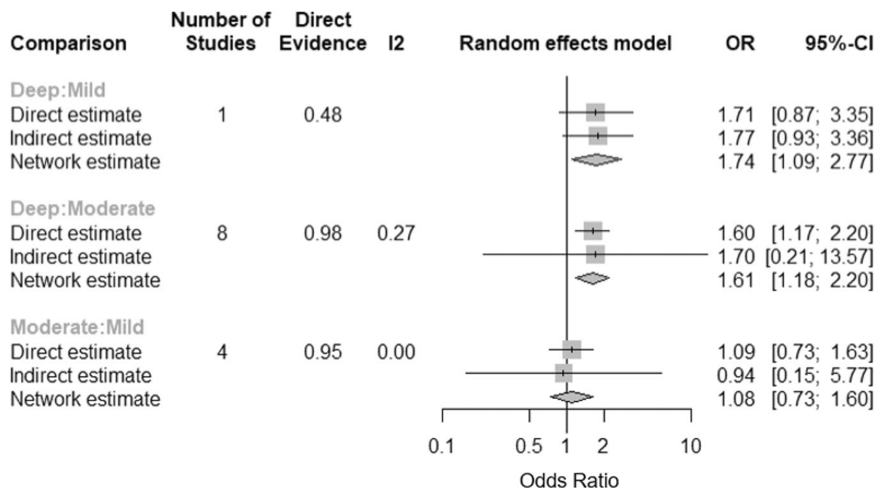

FIGURE 6 Forest plot of net split results of direct, indirect evidence and network estimates for the postoperative incidence of stroke (randomized controlled trials and propensity score matched studies).

4 | DISCUSSION

The optimal cerebral protection strategy during aortic arch surgery remains controversial. The main finding of this network meta-analysis is that the application of moderate and mild hypothermia in combination with selective cerebral perfusion is associated with lower incidence of postoperative stroke, when compared with DHCA alone or in combination with any selective cerebral perfusion strategy. To the best of our knowledge, this is the first network meta-analysis on the three most commonly used hypothermia levels.

Historically, the implementation of DHCA seemed to be safe under 40 min.[16] The general impression exists among the surgeons that lower temperatures are safer. Despite well-recognized complications of deep and profound hypothermia, wide-ranged implementation of moderate temperatures is not fully adopted. This emerges from concerns that still exist due to suboptimal organ protection of non-DHCA approaches, even with the addition of selective cerebral perfusion.[17]

Recently the collaborative efforts of the ARCH registry have resulted in more published global data on this topic. Keeling et al.[18] reported the outcomes of 3265 patients from the ARCH International aortic database who underwent total aortic arch replacement with either MHCA or DHCA in conjunction with ACP. Comparing the results of 669 propensity-score matched pairs, despite shorter CPB, ACC, and cerebral perfusion times in MHCA group, no significant differences in operative mortality and postoperative neurological complications were found.

The collaborative effort of the same investigators resulted in the meta-analysis by Tian aet al.[4] in which they included nine studies comparing DHCA with MHCA in conjunction with ACP. In line with our findings, they reported significantly higher permanent neurological dysfunction in the DHCA group compared with MHCA in combination with ACP. A more recent pairwise meta-analysis by Tian et al.[5] compared “cold” with “warm” hypothermic circulatory arrest groups in conjunction with ACP. Mean hypothermic circulatory arrest temperatures were 20.3°C and 26.5°C in the cold and warm groups, respectively. Significantly more emergent cases were in the “cold” hypothermia group. At the same time, the proportion of total aortic arch replacements and bilateral ACP were similar. In line with our founding, warmer temperatures showed significantly reduced perioperative mortality. Furthermore, they found a significant reduction in transient neurologic dysfunction, postoperative dialysis, ventilation duration and intensive care unit stay compared with colder hypothermic circulatory arrest. No significant reduction in postoperative stroke was found.

Our sensitivity analysis of solely RCT and PSM studies revealed that DHCA is associated with sustained higher postoperative risk of stroke when compared with MHCA and mild HCA in combination with selective cerebral perfusion. There was also a sustained significantly higher risk of operative mortality for MHCA when compared with mild HCA. Though further differences between DHCA, MHCA and mild HCA for the outcome operative mortality are not holding up. Reason behind this result could be underpowered analysis or the adjusted confounding associated with the network meta-analysis in unadjusted observational studies.

There is sparse published data on the effect of hypothermia level on postoperative spinal, renal and liver function. Recently, Liang et al. compared the impact of MHCA with DHCA on postoperative renal function by performing a pairwise meta-analysis of 14 observational studies.[6] They concluded that MHCA significantly reduced the postoperative incidence of renal failure and the need for renal replacement therapy. Unfortunately, we were unable to find any differences in the postoperative occurrence of AKI.

The shift towards warmer temperatures persists but is not uniform.[17] The same restraint exists in the adaptation of more evolved selective cerebral perfusion techniques, such as unilateral cerebral perfusion.[19] Skeptics advocate that it might not sufficiently supply the contralateral hemisphere and cause undetectable transient neurological injuries by conventional imaging methods.[20]

As the debate about optimal cerebral protection continues, this comprehensive network-meta analysis incorporating the existing data illustrates that despite the current concerns about warm cooling temperatures, moderate and mild hypothermic circulatory arrests in conjunction with selective cerebral perfusion provide improved data are that may support daily practice as well as direct designs of future multicentric randomized controlled trials in this regard.

4.1 | Strengths and limitations

The results of this network meta-analysis must be interpreted in light of its limitations. Several important limitations arise from the use of observational studies in a meta-analysis. The presence of unmeasured confounders and possible treatment allocation bias cannot be excluded. Ideally, a network meta-analysis is performed solely with the inclusion of randomized populations to guarantee that the relative treatment effects deriving from the network analysis remain unbiased.[21] However, the randomized evidence regarding the topic of hypothermic strategies in aortic arch surgery is scarce, leading to a relatively large amount of non-randomized studies in our network meta-analysis. Hence, incorporating both types of data allows assessments of larger sample sizes and multiple treatments simultaneously. Furthermore, there may be variability in surgeon and center expertize, technical variabilities and postoperative protocols. Additionally, heterogeneity may arise due to different definitions for stroke and postoperative AKI. Most studies included in the current analysis have been published recently, only one study dates from over 30 years ago. This study was not included in the sensitivity analysis.

5 | CONCLUSION

In the present network meta-analysis, the risk of operative mortality decreased with the use of mild HCA. Furthermore, the use of DHCA was associated with substantial higher risks of postoperative incidence of stroke when compared with the application of moderate-to-mild hypothermia management in combination with selective cerebral perfusion. These outcomes were reinforced by the sensitivity analysis of RCTs and PSM studies. Our findings call attention to and further highlight the unique challenges in selecting and managing temperature in aortic arch surgery. Future prospective high-quality research studies are warranted to allow better outcomes in this complex surgical procedures.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ORCID

Maximiliaan L. Notenboom http://orcid.org/0000-0002-3828-6775

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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