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Review

Pulse check accuracy in pediatrics during resuscitation: a systematic review

Stephan Katzenschlager[a,*], *Jason Acworth*[b,c], *Lokesh Kumar Tiwari*[d], *Monica Kleinmann*[e], *Michelle Myburgh*[f], *Jimena del Castillo*[g], *Vinay Nadkarni*[h], *Thomaz Bittencourt Couto*[i,j], *Janice A. Tijssen*[k], *Laurie J. Morrison*[l], *Allan DeCaen*[m], *Barnaby R. Scholefield*[n], *on behalf of International Liaison Committee on Resuscitation ILCOR ILCOR Pediatric Life Support Task Force*[1]

Abstract

Aim of the study: Current guidelines advise rescuers to initiate cardiopulmonary resuscitation if a child is unresponsive, not breathing normally, and shows no signs of life. Manual pulse checks are considered unreliable and time-consuming. This systematic review evaluates the accuracy and duration of recommended pulse check methods during pediatric cardiac arrest and explores emerging diagnostic techniques.

Methods: For this systematic review (PROSPERO ID CRD42024549535) three databases (PubMed, Embase, and Cochrane) were searched for articles published on this topic. An initial search was conducted on April 24, 2024, with an updated search using the same search strategy on February 16, 2025. Two authors independently screened the articles. One author extracted the data while a second author double-checked it. Quality and certainty of the evidence were evaluated using the QUADAS-2 and GRADE tools evaluated the evidence's quality and certainty. Studies were included if they compared manual pulse checks against alternative pulse check sites or other methods in pediatric patients. The data is presented descriptively.

Results: A total of three studies were included. These studies involved 39 pediatric patients and a total of 376 pulse checks. Out of the 47 infants and children included, only 14 were in cardiac arrest. The remaining 33 patients were on mechanical circulatory support with either VA-ECMO or LVAD. In total, 183 nurses and 181 physicians performed 376 pulse or ultrasound checks. Due to their specialty, 122 nurses and 89 doctors were classified as experienced. Sensitivity and specificity of manual pulse check ranged from 76 to 100% and 64–79%, respectively. When experienced providers conducted pulse checks, sensitivity and specificity were higher (76–100% and 62–82%, respectively) compared to inexperienced providers (67–82% and 44–95%).

The mean duration of pulse checks was 20 s, with an accuracy of 85%.

Conclusion: Despite high heterogeneity among included studies, manual pulse checks only achieved moderate accuracy with a prolonged duration. This suggests that manual pulse checks are unreliable in children for determination cardiac arrest state and need for ongoing CPR.

Keywords: Pediatric Life Support, Pulse check, Systematic Review, Cardiac arrest, Resuscitation

Introduction

When trying to determine if a child or adult is experiencing cardiac arrest, it is currently recommended for lay rescuers to not rely solely on palpating a pulse. Lay rescuers are persons who respond to a cardiac arrest are not obligated to do so as part of their employment.[1] If a child is unresponsive and not breathing normally, and there are no other signs of life, cardiopulmonary resuscitation (CPR) should be initiated. Due to the uncertainty and potentially fatal consequences of not performing CPR on a patient without a pulse, guidelines have dropped the pulse check for lay rescuers.[2]

* Corresponding author at: Heidelberg University, Medical Faculty Heidelberg, Department of Anaesthesiology, Heidelberg, Germany, Im Neuenheimer Feld 420, 69120 Heidelberg, Germany.

E-mail address: stephan.katzenschlager@med.uni-heidelberg.de (S. Katzenschlager).

[1] The members of the collaborator group are listed in Appendix A at the end of the article.

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In contrast, healthcare providers (defined as clinicians trained in cardiac arrest treatment) are advised to start CPR unless they can feel a pulse within 10 s.[3] Guidelines recommend a manual pulse check during CPR rhythm checks to detect a return of spontaneous circulation (ROSC). Palpating the carotid artery is recommended for children > 1 year, while the brachial artery is recommended in infants $\leq$ 1 year.[4]

Due to the perceived unreliability of manual pulse checks, other techniques have emerged over recent years. Due to the anatomic differences, cardiac auscultation may be easier to conduct in children than in adults. In in-hospital settings, arterial lines are the gold standard for invasive hemodynamic monitoring. Ultrasound is an emerging tool with the potential to decrease "hands-off" time during CPR and increase the accuracy of pulse checks. Prolonged manual pulse detection phases have been reported across the cardiac arrest population.[5] For in-hospital cardiac arrest, end-tidal CO_2 ($etCO_2$) has been proven to be a reliable marker for ROSC detection.[6] In a multicenter observational study, $etCO_2$ values above 20 mmHg were associated with a higher ROSC rate.[7]

Near-infrared spectroscopy (NIRS) has been explored for its potential to assist in detecting a perfusing rhythm during pulse checks.[8–9] Higher cerebral NIRS values during cardiac arrest were associated with ROSC and good neurological outcomes.[10–11] The role of NIRS in detecting a perfusing rhythm is still being determined.

This systematic review aims to identify the accuracy and duration of the recommended pulse check methods during cardiac arrest in pediatric patients. It also evaluates any new methods for pulse checks or ROSC detection.

Materials and methods

This systematic review was commissioned by the International Liaison Committee on Resuscitation (ILCOR) Pediatric Life Support Task Force.

The protocol for this systematic review was developed in accordance with the ILCOR framework and registered on PROSPERO (ID CRD42024549535) on June 1st, 2024. It was conducted following the Cochrane Handbook for Systematic Reviews of Diagnostic Test Accuracy[12] and reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist (Supplement Text 1 Checklist).[13]

Search strategy

Following Cochrane standards for systematic reviews, a professional librarian searched three databases (PubMed, Embase, and Cochrane). Although searching trial registries was pre-planned, this was not carried out due to the task force's awareness that no studies are currently planned. The main search terms were "cardiac arrest", "pediatric", "infant", and "pulse check" and checked against an expert-assembled list of relevant papers. The full search strategy is presented in the Supplements (Supplement Text 2 Search Strategy).

We conducted the search without applying any language, age, or geographic restrictions from inception until April 24, 2024, and updated the search on February 16, 2025. The update was performed using the same search strategy and all three databases.

Eligibility criteria

We included studies that followed the PICOST scheme in Table 1.

Study selection and data synthesis

Two authors (SK and JA) independently reviewed the titles and abstracts of all articles identified in the search. In the event of disagreement, both authors were unblinded to discuss and resolve the conflict. The two reviewers then independently reviewed the full-text papers, masking the decisions of the other reviewer. They identified articles meeting the inclusion criteria. Disagreements were resolved by discussion. Study selection and screening were performed using Covidence (https://www.covidence.org).

Data extraction was performed sequentially, with one reviewer extracting the data and risk of bias assessment. Afterwards, the second reviewer double-checked the extracted data. Data extraction was performed with the help of Microsoft Excel. This approach deviated from the planned registration due to the time-sensitive nature of this review.

True positive, false negative, false positive, and true negative were defined in Fig. 1:

Sensitivity and specificity were calculated if study authors did not present them within the manuscript.

Subgroups for the systematic reviews were predefined based on the following characteristics: pulse check site (femoral, brachial, carotid) and healthcare provider experience (experienced versus inexperienced). Due to the low number of studies, *meta*-analysis was not performed, and the data is presented descriptively. The preplanned statistical methods are presented in the supplement (Supplement Text 3 Statistical Methods).

Risk of bias assessment

Details and an interpretation guide for the risk of bias assessment are presented in the supplementary material (Supplement Text 4 QUADAS). This assessment was conducted by one author (SK) and supervised by another (JA).

Certainty of evidence (CoE) assessment

Two critical outcomes (sensitivity and specificity) and one important outcome (duration of pulse check) were defined by consensus within the ILCOR Pediatric Life Support Taskforce. For each outcome, the Certainty of Evidence (CoE) was assessed following the GRADE guidelines.[15] After rating the respective study type and assessing for publication bias (e.g., randomized controlled trial or observational trial; number of studies, sample size),[16] each outcome was independently evaluated using five categories: study design, risk of bias (RoB), inconsistency, indirectness, and imprecision.

Results

After removing duplicates, the search strategy returned 1280 titles. Of those, 19 were sought for full-text screening, and three studies were included in the systematic review (Fig. 2).[17–19]

Two studies were performed in Australia, and one was conducted in the United States.

Risk of bias assessment

The quality of clinical accuracy studies was assessed by applying the quality assessment of studies of diagnostic accuracy (QUADAS-2) tool, which was adjusted to the needs of this review.[20] The included studies were of variable bias and applicability.

Two studies had a low risk of bias.[18,19] However, their applicability was determined to be high risk, as the studies were performed on

Table 1 – Population, intervention, comparison, outcomes, study design, and time frame for study inclusion.	
Population	Infants and children in any setting (out of hospital or in-hospital) with suspected cardiac arrest when assessing whether to start or continue CPR
Intervention	any other site for pulse check (e.g. femoral pulse, etc) or method (not exclusively, cardiac auscultation, pulse oximetry, ultrasonography, rise in end-tidal CO_2 values above specific thresholds, invasive monitoring, etc)
Comparison	pulse check as per current guidelines by healthcare providers (brachial pulse for infants and carotid pulse for children and adolescents)
Outcomes	Any outcome including but not limited to: The Pediatric Life Support Taskforce prefers outcomes defined in the Pediatric Core Outcome Set for Cardiac Arrest publication • accuracy, defined as sensitivity and specificity of detecting a perfusing rhythm • duration of cardiac compression pauses • any clinical outcome
Study Design	Randomized controlled trials (RCTs) and non-randomized studies (non-randomized controlled trials, interrupted time series, controlled before-and-after studies, cohort studies) that directly concern the population and intervention described above are eligible for inclusion. The minimum number of cases for a case series to be included was set by the PLS TF at 5. Unpublished studies (e.g., conference abstracts, trial protocols) were excluded. All relevant publications in any language were included as long as there was an English abstract.
Time frame	All years

Abbreviation: PLS = pediatric life support; TF = task force; P-COSCA = pediatric core outcome set for cardiac arrest.

		Comparator/Reference standard	
		Cardiac arrest present	Cardiac arrest absent
Intervention	"Pulse absent"	True positive	False positive
	"Pulse present"	False negative	True negative

Fig. 1 – Definition of True positive, False negative, False positive, and True negative.

patients receiving veno-arterial extracorporeal membrane oxygenation (VA ECMO) or a left ventricular assist device (LVAD) with and without spontaneous pulsatile flow (Table 2. Therefore, they indirectly mimic cardiac arrest. One study had a high risk of bias; in contrast, the applicability was low risk, as this study was performed during cardiac arrest.[17] A high risk of publication bias existed due to two small studies published by the same research group.

Certainty of evidence (CoE) assessment

In accordance with the GRADE recommendations, every study was downgraded for serious risk of bias risks. Regarding indirectness, two studies were downgraded to a serious risk of bias.[18,19] In contrast, all studies were downgraded for imprecision to a very serious risk of bias for sensitivity and a serious risk of bias for specificity (Table 3).

Study description

Two studies were conducted in the intensive care unit (ICU), while one was performed in the emergency department. Out of the 47 infants and children included, only 14 were in cardiac arrest. The remaining 33 patients were on mechanical circulatory support with either VA-ECMO or LVAD.

In total, 183 nurses and 181 physicians performed 376 pulse or ultrasound checks.

Due to their specialty, 122 nurses and 89 doctors were classified as experienced.

Accuracy

For the critical outcome of accuracy (defined as sensitivity and specificity), this systematic review identified three studies with 39 patients and 376 pulse checks, providing very low certainty of evidence. All studies had a serious risk of bias. Two studies compared arterial line monitoring with manual pulse checks.[18,19] These were downgraded for imprecision as the patients were on mechanical circulatory support, which was used as indirect evidence. Those resulted in a range of sensitivity and specificity from 76% to 86% and 64% to 79%, respectively.

One study assessed the accuracy of ultrasound in comparison to standard resuscitation measures such as a rise in end-tidal CO2, the

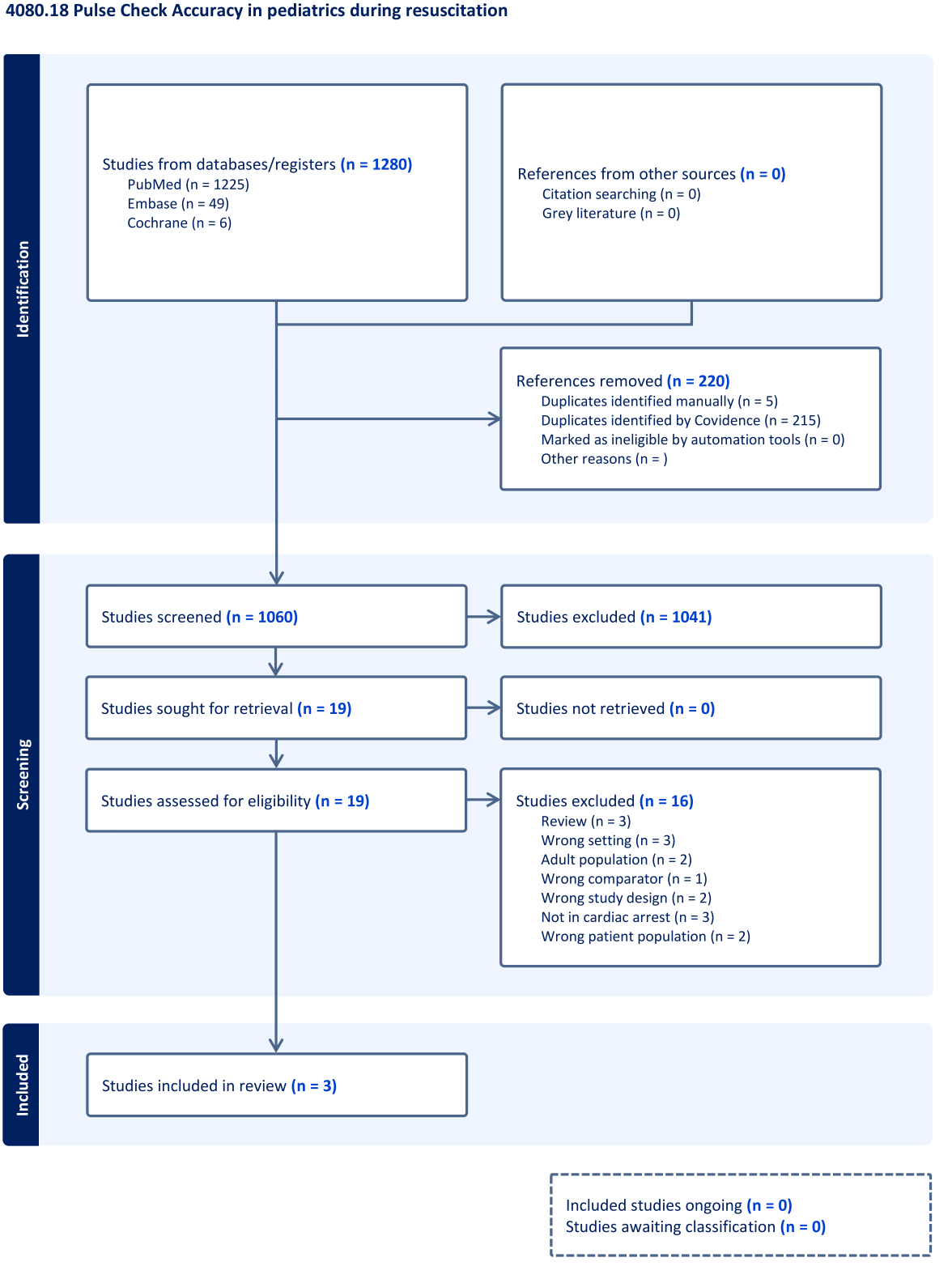

Fig. 2 – PRISMA flow diagram.

Table 2 – Risk of Bias and applicability assessment based on the QUADAS-2 assessment tool.

	Selection of participants	Index Test	Reference Standard	Flow and Timing
Study	**RoB / Applicability**	**RoB / Applicability**	**RoB / Applicability**	**RoB**
Tsung 2008	High / Low	Unclear / Low	High / Low	Low
Tibbals 2009	Low / High	Low / Low	Low / Low	Low
Tibbals 2010	Low / High	Low / Low	Low / Low	Unclear

Abbreviation: RoB = Risk of Bias

presence of a pulse, or spontaneous movement without chest compressions.[17] In all cases, the ultrasound exam was in concordance with the pulse check result and the clinical exam (Fig. 3a,b).

Sensitivity and specificity among experienced healthcare personnel ranged from 78% to 100% and 62% to 82%, respectively.[18–19] In contrast, sensitivity among inexperienced healthcare personnel ranged from 67% to 82%, with a wide specificity range from 44% to 95%[18–19] (Fig. 3c,d).

One study reported accuracy according to the pulse check site.[19] Brachial palpation ($n = 125$) resulted in a sensitivity and specificity of 86% and 67%, respectively. Femoral palpation ($n = 70$) had a similar sensitivity and specificity of 85% and 56%, respectively.

Duration of cardiac compression pauses

No studies in infants and children were identified that directly assessed this outcome. One study evaluated the time until a decision was made about whether a pulse was present or not. However, this study was performed in children on left ventricular assist devices (LVAD) or extracorporeal membrane oxygenation (ECMO).[18] In this study, only 39% (60/153) of the participants decided on the presence of a pulse within ten seconds. The mean duration until any decision was made was 20 s (standard deviation 17 s), with an accuracy of 85%. Inexperienced providers took longer to make their decisions. This indirect evidence indicates that there is a reasonable concern about prolonged chest compression pauses, especially in inexperienced clinicians. This evidence was gained in a less critical setting with perfused children with warm skin temperature and brisk capillary refill time.

Discussion

This is the first systematic review of pulse check accuracy in children with cardiac arrest. It critically evaluates the reliability of manual pulse palpation during pediatric cardiac arrest and highlights significant implications for clinical practice and resuscitation guidelines. Our analysis reveals that manual pulse checks, even among experienced healthcare providers, are often inaccurate and time-consuming. This suggests a need to reassess current protocols that rely heavily on this method.

We considered the importance of sensitivity and specificity in presenting a detailed accuracy assessment. The aim is to identify weaknesses in various clinical situations, e.g., in people with cardiac arrest who are categorized as “pulse present”.

Our findings indicate that the sensitivity and specificity of manual pulse palpation in pediatric patients with cardiac arrest vary widely, ranging from 76% to 100% and 64% to 79%, respectively.[17–19] Notably, the mean duration for pulse assessment was approximately 20 s, exceeding the recommended maximum of 10 s.[18] This compares to a median of 15, 12, and 21 s for femoral, brachial, and carotid pulse checks, respectively.[21]

While clinical experience is generally associated with improved diagnostic skills, our review demonstrates that even seasoned practitioners exhibit considerable variability in pulse palpation accuracy. Studies have shown that the sensitivity and specificity among experienced providers range from 76% to 100% and 62% to 82%, respectively.[18,19] This inconsistency suggests that factors beyond clinical experience, such as the stressful environment of resuscitation and the subtlety of pediatric pulses, may affect the reliability of manual pulse checks. Consequently, there is a compelling need to explore alternative, more objective methods for pulse checks in pediatric cardiac arrest.[22] An observational study, not included in this systematic review, assessing caregivers’ ability to detect a pulse in sleeping infants revealed a notably low detection rate of 23% for the carotid pulse. In contrast, 86% could palpate a pulse at the brachial artery.[23] Simulation-based manikin studies overestimate the diagnostic accuracy of inexperienced medical personnel or laypersons in pulse detection.[24–25] Resuscitation Council guidelines have recommended different approaches to initiate CPR in children. The European Resuscitation Council recommends that all providers assess signs of life and not lose time by checking for a pulse.[26] In contrast, the American Heart Association recommends that healthcare providers consider assessing for a pulse as long as the initiation of CPR is not delayed more than 10 s.[27] However, our review highlights that manual pulse checks frequently exceed this timeframe and are prone to inaccuracies. In light of these findings, it is imperative to reconsider the emphasis on manual pulse checks in resuscitation protocols. Future guidelines should contemplate de-emphasizing manual pulse palpation in favor of no delay in starting resuscitation until we have sufficient evidence to suggest other tools may help, such as ultrasound or etCO2 monitoring, to enhance the determination of the need for resuscitation.

The widespread availability of ultrasound and etCO2 monitoring opens new opportunities for potentially faster and more reliable pulse checks. These methods should be tested in clinical trials compared to the current gold standard.

A prospective observational trial found that apical or subxiphoid views of the heart to assess contractility can be obtained within 10 s in 86% and 94%, respectively. The femoral view showed a slightly worse result, with 74% of the scans being interpretable for pulsatility within 10 s.[28] A dedicated ultrasound protocol for pediatric cardiac arrest coupled with supervised training may increase the rates of interpretable views within 10 s.[29] Given the limitations identified with manual pulse palpation, incorporating technological adjuncts into resuscitation protocols may enhance the accuracy and efficiency of circulatory assessment.

Additionally, modalities such as near-infrared spectroscopy (NIRS) and end-tidal carbon dioxide ($EtCO_2$) monitoring offer real-

Table 3 – Certainty of Evidence for pulse check vs. arterial blood pressure or echocardiography assessment using the GRADE approach.

Outcome	of studies (of patients)	Study design	Factors that may decrease certainty of evidence					Effect per 1,000 patients tested			Test accuracy CoE	Importance
			Risk of bias	Indirectness	Inconsistency	Imprecision	Publication bias	pre-test probability of0.8%	pre-test probability of1%	pre-test probability of10%		
True positives (patients with return of spontaneous circulation)	3 studies	cohort & case-control type studies	Serious,[17–19] [a]	not serious[a]	not serious	very serious[18,19b]	serious	6 to 8	8 to 10	76 to 100	⊕◯◯◯ Very low,[17–19] [a,b]	CRITICAL
False negatives (patients incorrectly classified as not having return of spontaneous circulation)								0 to 2	0 to 2	0 to 24		CRITICAL
True negatives (patients without return of spontaneous circulation)	3 studies	cross-sectional (cohort type accuracy study)	serious,[18,19] [b]	serious[18,19b]	not serious	serious[18,19b]	serious	635 to 784	634 to 782	576 to 711	⊕○○○ Very low, [b]	CRITICAL
False positives (patients incorrectly classified as having return of spontaneous circulation)								208 to 357	208 to 356	189 to 324		CRITICAL
Inconclusive	0 studies	–	–	–	–	–	–				–	
Complications	0 studies										–	

Explanations: a. One study (Tsung) evaluated patients with knowledge about the reference test. b. Two studies (Tibballs) evaluated patients on ECMO and LVAD systems. Those were not in cardiac arrest, the mechanical circulatory support system was used to mimic cardiac arrest.

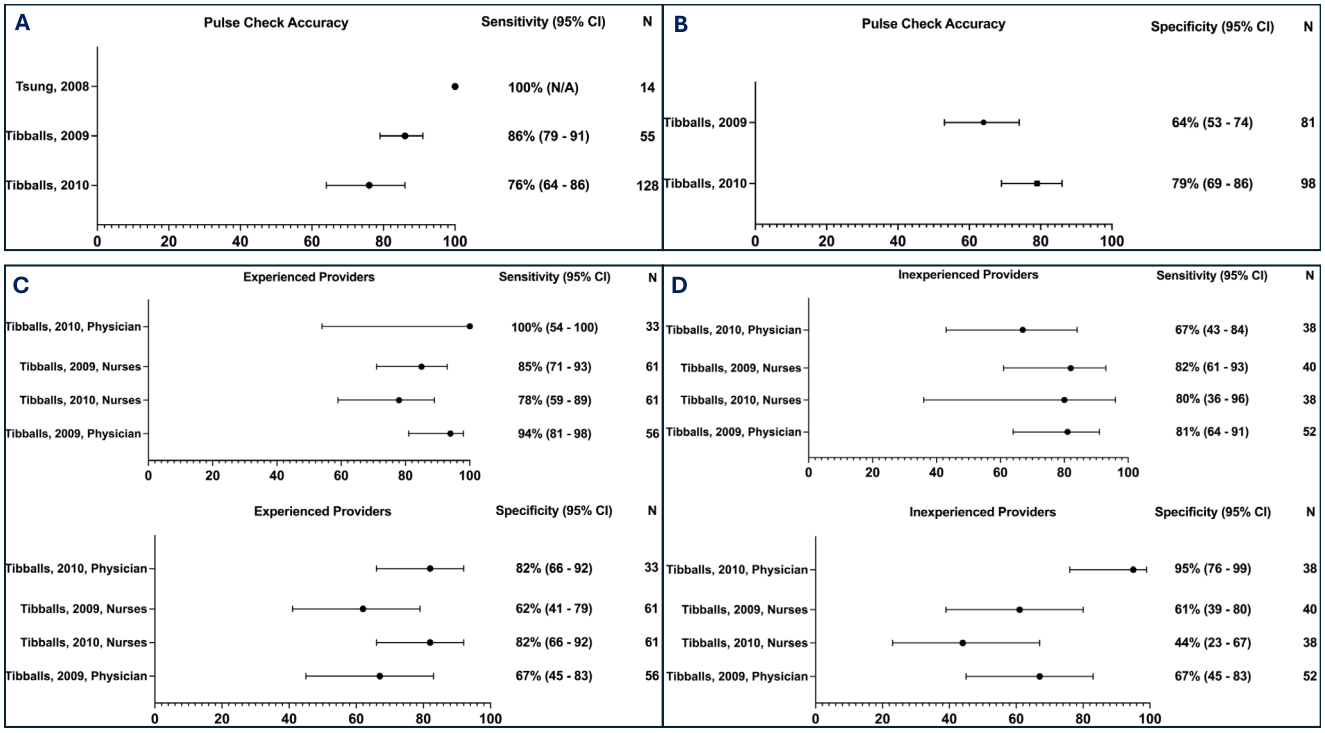

Fig. 3 – a-d – Forest Plots presenting the accuracy of the included studies. Abbreviations: CI = confidence interval.

time insights into tissue perfusion and metabolic status, potentially serving as valuable adjuncts in determining the presence of a perfusing rhythm.

Studies have demonstrated that higher intra-arrest regional cerebral oxygen saturation (rSO_2) measured by NIRS is associated with increased ROSC rates and improved survival to hospital discharge in pediatric patients.[11,30] Similarly, elevated $etCO_2$ levels during pediatric cardiac arrest have been correlated with higher ROSC rates and better survival outcomes, suggesting that $etCO_2$ monitoring can serve as a valuable tool during pediatric resuscitation.[31] These findings underscore the potential of NIRS and $etCO_2$ monitoring to enhance the accuracy of circulatory assessments and guide resuscitative efforts in pediatric cardiac emergencies.

All studies included in this systematic review were performed in hospitals. However, two included inexperienced physicians and nurses, increasing their generalizability. Due to different circumstances in the out-of-hospital setting, the studies' transferability is limited. Although this systematic review was performed following the standardized guidance by ILCOR, it has limitations. (A) Due to the indirectness and high heterogeneity of the included studies, no *meta*-analysis was performed. (B) No randomized controlled trials compared the intervention with standard care in the pediatric population were identified. (C) The review included only diagnostic accuracy studies, potentially neglecting evidence from observational studies without a comparator.

Future research should focus on evaluating the feasibility and effectiveness of alternative assessment methods in pediatric resuscitation to address the challenges associated with manual pulse palpation. Clinical trials investigating the integration of ultrasound, NIRS, and $etCO_2$ monitoring into standard resuscitation protocols are essential to determine their impact on diagnostic accuracy and patient outcomes. Moreover, studies exploring the potential of these technologies to determine if a child is in cardiac arrest could provide valuable insights. Ultimately, a paradigm shift towards utilizing objective measures of perfusion and oxygenation may enhance the efficacy of pediatric resuscitation efforts and inform the development of evidence-based guidelines. Further examination of the potential longer hands-off time and their impact on outcome would also be helpful. For comparability, these studies would benefit from including outcome measures consistent with the Pediatric Core Outcome Set for Cardiac Arrest recommendations.[14]

Conclusion

This first systematic review of in-hospital pulse check accuracy for children identified moderate accuracy with very low certainty of evidence. As determining a perfusing rhythm is a high-stakes test, this level of accuracy suggests that the currently recommended pulse check sites are inaccurate compared to invasive blood pressure measurement ultrasound and should, therefore, not be used as the sole determinant of starting CPR in an unresponsive child.

CRediT authorship contribution statement

Stephan Katzenschlager: Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation. **Jason Acworth:** Writing – review & editing, Writing – original draft, Validation, Supervision, Conceptualization. **Lokesh Kumar Tiwari:** Writing – review & editing. **Monica Kleinmann:** Writing – review & editing. **Michelle Myburgh:** Writing – review & editing. **Jimena del Castillo:** Writing – review & editing. **Vinay Nadkarni:** Writing – review & editing. **Thomaz Bittencourt Couto:** Writing – review & editing. **Janice**

A. Tijssen: Writing – review & editing. **Laurie J. Morrison:** Methodology, Supervision, Writing – review & editing. **Allan DeCaen:** Writing – review & editing, Validation, Supervision, Conceptualization. **Barnaby R. Scholefield:** Writing – review & editing, Validation, Supervision, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

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Author details

on behalf ofInternational Liaison Committee on Resuscitation ILCOR ILCOR Pediatric Life Support Task Force[1] *[a]Heidelberg University, Medical Faculty Heidelberg, Department of Anaesthesiology, Heidelberg, Germany [b]Emergency Department, Queensland Children's Hospital, Australia 501 Stanley St, South Brisbane, QLD 4101, Australia [c]Faculty of Medicine, University of Queensland, St Lucia, QLD 4072, Australia [d]Division of Pediatric Pulmonology and Intensive Care, Department of Pediatrics, All India Institute of Medical Sciences, Rishikesh, India [e]Department of Anesthesiology, Critical Care and Pain Medicine, Boston Children's Hospital and Harvard Medical School, Boston, MA, United States [f]Department of Paediatrics and Child Health, University of the Free State, Bloemfontein, South Africa [g]Pediatric Intensive Care Department, Hospital General Universitario Gregorio Maranon de Madrid, Spain [h]Department of Anesthesia and Critical Care Medicine, Children's Hospital of Philadelphia, University of Pennsylvania Perelman School of Medicine, United States [i]Centro de Simulação Realística and Faculdade Israelita de Ciências da Saúde, Hospital Israelita Albert Einstein, Brazil [j]Pronto Socorro, Instituto da Criança e do Adolescente do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, Brazil [k]Children's Hospital, London Health Sciences Centre, Paediatric Critical Care Medicine, Department of Paediatrics, Western University, Canada [l]Sunnybrook Health Sciences Centre, University of Toronto, Toronto, ON, Canada [m]University of Alberta, Pediatric Critical Care Medicine, Edmonton, Canada [n]Department of Critical Care Medicine, Hospital for Sick Children, ON, Canada*

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