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Review

International facets of the 'chain of survival' for out-of-hospital and in-hospital cardiac arrest – A scoping review

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Abstract

Background: The "chain of survival" was first systematically addressed in 1991, and its sequence still forms the cornerstone of current resuscitation guidelines. The term "chain of survival" is widely used around the world in literature, education, and awareness campaigns, but growing heterogeneity in the components of the chain has led to confusion. It is unclear which of these emerging chains is most suitable, or if adaptations are needed in particular contexts to depict key actions of resuscitation in the 21st century. This scoping review provides an overview of the variety of chains of survival described.

Objectives: To identify published facets of the chain of survival, to assess views and strategies about adapting the chain, and to identify reports on how the chain of survival affects teaching, implementation, or patient outcomes.

Methods, eligibility criteria, and sources of evidence: A scoping review as part of the continuous evidence evaluation process of the International Liaison Committee on Resuscitation (ILCOR) was conducted. MEDLINE(R) ALL (Ovid), Embase (Ovid), APA PsycINFO (Ovid), CINAHL (Ebscohost), ERIC (Ebscohost), Web of Science (Clarivate), Scopus (Elsevier), and Cochrane Library (Wiley Online) were searched. All publications in all languages describing chains of survival were eligible, without time restrictions. Due to the heterogeneity and publication types of the relevant studies, we did not pursue a systematic review or meta-analysis.

Results: A primary search yielded 1713 studies and after screening we included 43 publications. Modified versions of the chain of survival for specific contexts were found (e.g., in-hospital cardiac arrest or paediatric resuscitation). There were also numerous versions with minor adaptations of the existing chain. Three publications suggested an impact of the use of the chain of survival on patient outcomes. No educational or implementation outcomes were reported.

Conclusion: There is a vast heterogeneity of chain of survival concepts published. Future research is warranted, especially into the concept's importance concerning educational, implementation, and clinical outcomes.

Keywords: Chain of survival, Chainmail of survival, Out-of-hospital cardiac arrest, OHCA, Cardiopulmonary resuscitation, CPR, Scoping review

Introduction

The "chain of survival" was first systematically described in an American Heart Association (AHA) statement in 1991,[1] and dates back to similar concepts by Friedrich Wilhelm Ahnefeld[2] or the first steps of modern cardiopulmonary resuscitation (CPR) by Peter Safar.[3] The AHA statement posited that "more people can survive sudden cardiac arrest when a particular sequence of events occurs as rapidly as possible".[1] Over thirty years later, the concept is still applicable

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today: The sequence of "Early access", "Early CPR", "Early defibrillation", and "Early advanced care"[1] remain the cornerstone of all current resuscitation guidelines.[4] The AHA defines the "chain of survival" as [...] the critical actions that must occur in rapid succession to maximize the chance of survival from cardiac arrest" and refers to it in its most recent CPR guidelines.[5] The European Resuscitation Council (ERC) also uses the term in its latest guidelines and describes the "chain of survival" as "the actions linking the victim of sudden cardiac arrest with survival [...]", and closely links it to the "formula for survival" (Medical Science × Educational Efficiency × Local Implementation = Survival).[6,7]

However, only the AHA uses various iterations of the chain of survival, for adult and paediatric out-of-hospital cardiac arrest (OHCA), and for adult and paediatric in-hospital cardiac arrest (IHCA) in their current guidelines.[4] The ERC switched to "systems saving lives", and, while still mentioning the chain of survival, does currently not use a depiction of the chain of survival.[8]

The term "chain of survival" is nowadays widely used around the world in literature, scientific and popular presentations, education, and awareness campaigns. Also, there is growing heterogeneity in the links depicted in the "chain of survival", which leads to confusion about which version should be used in a given context. It is not currently known if applying different chains also leads to differences in outcomes in education, implementation, or patients after cardiac arrest. Also, beyond the context of cardiac arrest, the chain of survival has been modified to cover a range of critical conditions. A simple google search of the chain of survival returns a wide variety of chains of survival often produced by a particular body to suit their purpose. This bears the risk that increasing variations may lead to reduced patient outcomes if modified links in the chains are not evidence-based. It is therefore important to understand which variations exist in evidence-based literature.

We thus aimed to provide an overview of the various chains of survival, to assess views and strategies about its adaptation, and assess if there were reports on the chain of survival concept affecting teaching, implementation, or patient outcomes.

Methods

Protocol

This scoping review was conducted in the continuous evidence evaluation process of the International Liaison Committee on Resuscitation (ILCOR), together with seven members from the Education, Implementation and Teams (EIT) Task Force (SS, KGM, NF, KE, YCK, TM, AO, RG) and six external content experts (NF, CV, ZAH, HA, BB, JAO). The EIT Task Force agreed upon a review protocol including a search strategy, reflecting the current ILCOR processes for scoping reviews,[9] and following a recommended methodological framework[10] and the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) extension for Scoping Reviews (see checklist in Supplement 1).[11]

The PICOST question

The Population, Intervention, Comparator, Outcome, Study Design and Timeframe (PICOST) format was defined as follows:

- **Population:** Literature using the term "chain of survival" or similar terms (e.g., "survival chain", "chain of [other pathology]")
- **Intervention (or exposure):** Adaptations of the original "chain of survival"[1] ...
- **Comparison:** ...compared to the original "chain of survival"
- **Outcomes:**
  - Composition of the specific variations in adapted versions
  - Attitudes, rationale, and views concerning the adaptation
  - Incentives to develop novel versions
  - Way of implementation of adapted versions
  - Way of utilization of adapted versions in education
  - Variations in visualization
  - Effect of the use of the chain of survival or variants on teaching, implementation, patient outcomes
- **Study Design:** All types of studies – randomized or non-randomized (controlled) trials, observational studies, retrospective studies, reviews, non-original/narrative literature such as letters, commentaries, or editorials. All languages (translations were obtained when necessary). The Task Force originally also wanted to specifically screen grey literature and social media for content about the chain of survival. In correspondence with the information specialist, this was subsequently cancelled due to resource limitations and no clear definitions in the ILCOR evidence synthesis process of how to address grey literature in a structured way; however, this approach should be re-addressed in the future.
- **Time frame:** From the inception of the included databases to 19th of February 2024.

We excluded publications on the original chain of survival and included publications reporting a novel chain of survival or a modification to the original chain.

Inclusion criteria:

- Publications describing novel adaptations and/or modifications of the chain of survival.
- Publications describing various kinds of the chain of survival (e.g., for out-of-hospital cardiac arrest [OHCA] and for in-hospital cardiac arrest [IHCA]).
- Publications describing an implementation process or use of the chain of survival in an educational setting or awareness campaign.
- Publications describing potential effects of the chain of survival (the original one or modified versions) on outcomes.

Exclusion criteria:

- Publications only mentioning the chain of survival or describing the term in the original sense.
- Publications only emphasizing that individual links of the chain of survival must be "strengthened".
- Older publications suggesting additions to the chain of survival that were later adopted in the official version (in most cases this was a 5th link).
- Publications using the term chain of survival as a synonym for their "systems to save lives" program (e.g., description how the "chain of survival" was worked on when a new public access defibrillator program was implemented).

Search strategy and selection process

The search strategy (Supplement 2) was developed by an information specialist of the AHA, USA (Mary-Doug Wright) and

peer-reviewed by one of the Medical University of Vienna, Austria (asked not to be named). The records from database searches were downloaded and imported into an EndNote database for a removal of duplicates and subsequent screening. The databases searched were: MEDLINE(R) ALL (Ovid); Embase (Ovid); APA PsycINFO (Ovid); CINAHL (Ebscohost); ERIC (Ebscohost); Web of Science (Clarivate); Scopus (Elsevier); Cochrane Library (Wiley Online) – Cochrane Central Register of Controlled Trials Issue 7 of 12, July 2023, and Cochrane Database of Systematic Reviews Issue 8 of 12, August 2023. The final database searches were performed in August 2023. We then conducted a search update on the 19th of February 2024 which resulted in no additional relevant publications. The full search strategy can be found in Supplement 2. The abstracts were imported into Rayyan (rayyan.qcri.org) and screened independently by the authors. The reviewers collaborated to reach consensus if conflicts arose.

Synthesis of results

Data were extracted from the included publications. After data extraction, the reviewers met and reached a consensus on how to categorize the ideas within the articles included. We thus sorted the publication types into subgroups that were most suitable and internationally recognized (even though a specific journal may have classified a publication differently, e.g., "special report"), and thus report on four abstracts,[13–16] two commentaries,[17,18] five editorials,[19–23] ten letters,[24–33] five concepts,[34–38] three reviews,[39–41] four statements,[1,42–44] six reports of original research,[45–50] and four guidelines.[4,51–53] We further grouped the publications (Supplementary Table S1) into "novel kinds of the concept *related* to resuscitation" ($n = 8$),[1,4,18,30–32,49,51] "novel kinds of the concept *not directly related* to resuscitation" ($n = 23$),[14,16,17,19–23,28,29,33–35,37,38,40,41,43,45–47,52,53] "mere adaptations" ($n = 9$),[15,24–27,36,39,42,44] and "impact on outcomes" ($n = 3$).[13,48,50] We applied the World Bank definition to classify the countries of study origin into four categories by gross national income per capita to get an impression of the resource setting of the publications. The categories were: low-income economies, lower-middle-income economies, upper-middle-income economies and high-income economies.[12]

Despite the relatively large number of publications, heterogeneity and publication types made a systematic review or meta-analysis impossible.

Results

The reviewers screened 1704 abstracts. Nine additional abstracts were found as cross citations in the reviewing process, leading to a total of 1713 screened abstracts. Ten duplicates were deleted, and 469 articles underwent full-text retrieval. A further 426 publications were excluded leaving 43 articles to be included in the review. These publications originated from diverse geographical areas (Table 1), and there were large differences in the number of studies per region, with most originating in Europe ($n = 19$), followed by North America ($n = 12$). The majority ($n = 38$, 88%) came from high-income countries, and none from low-income countries.

Since the first description of the chain of survival in 1991,[1] there has been an increase in publications over the years, with an upward trend (Fig. 1).

For resuscitation, chains of survival were suggested in terms of additional versions for IHCA[4,32,51] and paediatric resuscitation,[4,30] a chain of survival for mass gatherings (including early planning),[49] a chainmail of survival (expanding the linear concept of the chain into an interconnecting lattice concept with many links which are adaptive to various settings and situations),[31] and a chain of survival specific to China (three phases, also including cultural specifics).[18]

Mere adaptations of the existing chain (mostly expansions of the chain) included extensions specific for survival after ventricular fibrillation (focusing on secondary prevention),[39] for rehabilitation,[27] general prevention,[42] or family support.[15] Also, there were suggestions of making the chain into a circle,[24] a more detailed description of the chain for ST-elevation myocardial infarction,[36] a variation of the chainmail of survival to low-resource settings,[44] a depiction of survival odds along the chain and associated research funding,[25] and a chain with a visual adaptation of the size of each link reflecting their relative contribution to survival.[26]

The impact of the chain of survival on patient outcomes was reported either as an observation of increased survival rates and better neurologic outcome after the introduction of the 5th link of the chain by the AHA in 2010,[48,50] and increased bystander CPR rates after a public campaign about the chain of survival in France.[13] No educational or other outcomes were identified.

Aside from concepts originally related to CPR, other versions or adaptations of the chain of survival which are not directly related to CPR were found,[14,16,17,19–23,28,29,33–35,37,38,40,41,43,45–47,52,53] for

Table 1 – Included studies per geographical region. Respective income classifications as per definition of the World Bank.[12]

Region	No. of studies	Countries
Africa	1	Nigeria (1) – *lower-middle*[1]
Australia & New Zealand	3	Australia (2), New Zealand (1) – *both high*[1]
Asia	5	Cambodia (1) – *lower middle*[1], China (1) – *upper-middle*[1], Japan (1) – *high*[1], South Korea (1) – *high*[1], Taiwan (1) – *high*[1]
Europe	19	Austria (2), Belgium (1), France (4), Norway (3), Spain (3), Switzerland (2), UK (4) – *all high*[1]
Middle East	1	Oman (1) – *high*[1]
North America	12	Canada (2), USA (10) – *both high*[1]
South America	2	Brazil (2) – *upper-middle*[1]
Total	**43**	

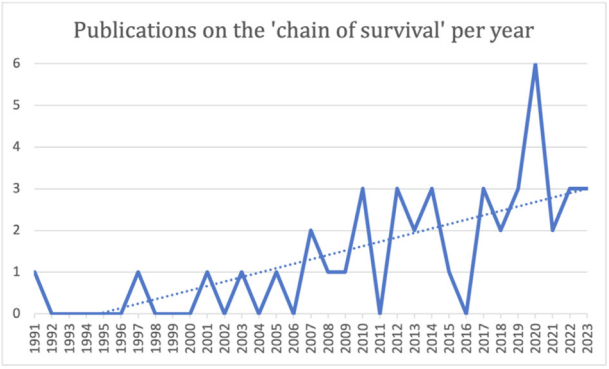

Fig. 1 – Publications on the chain of survival per year since its first description in 1991, with an upwards trend (dotted line). Search as of 03/2024 (not including publications from 2024) in Pubmed/Medline for the term "chain of survival" in titles and/or abstracts.

example for specific conditions like trauma[14,19,23] and severe haemorrhage,[40] land mine incidents,[46] stroke,[41,53] ST-elevation myocardial infarction,[20,22] drowning,[16,34] septic shock,[28]complicated deliveries,[45] occasions and situations (pandemics,[21,33] events,[38] terror attacks,[43] chemical/biological/radiological/nuclear incidents,[17] and industrial incidents[37]). Variations which re-thought the concept include the "survival ladder" (each step leads closer to success),[29] or a "chain of survival behaviours" in first aid (defining domains of first aid education).[52] As peculiarities, there was even an animal chain of survival for veterinary patients,[35] and one for anaesthesia equipment,[47] whereas the latter touches the important point of scarce resource settings.

Discussion

There is vast heterogeneity within the published literature on the chain of survival, ranging from a "classic" version, for instance used by resuscitation councils, to small adaptations, and, finally, to completely novel versions. New depictions of the chain of survival have expanded beyond cardiac arrest to other pathologies, professions, or situations. Also, there are novel technological developments that have been integrated into the chain of survival.[4,34,54,55] Such adaptations may be necessary but are applied inconsistently without a sound underlying system or evidence, which may lead to confusion. Ideally, any chain of survival should be evidence-based, and each evidence-based link needs to (or at least aim to) contribute to improved outcomes (e.g., patient, education, or implementation outcomes).

A one-size-fits-all concept?

Low- and middle-income countries and low-resource settings in general may require entirely different resource and priority allocations than high-resource environments, and in such circumstances evidence-based adaptations to the chain of survival should be encouraged. A chain of survival solely developed by people from high-income areas can limit true global implementation severely. A "universal" chain of survival would therefore have to be tailored to achieve international recognition and consider all resource settings.[44] Sub-versions would then again emerge due to the heterogeneity of the bespoke setting, ranging from local to system-wide levels. In any resource setting, end-user perspectives may cause further adaptations (e.g., a person providing first aid will find certain links less important than professional health care workers).

A dilemma arises: on the one hand, most healthcare workers involved in acute care will know one or another version of the chain of survival because the concept has penetrated the respective scientific literature, guiding documents, and other types of publications including grey literature. Also, the term "chain of survival" is often – clinically and scientifically – used as a synonym for whole systems of cardiac arrest care (ERC: "systems saving lives"). On the other hand, the growing number of publications and opinions on the topic, as well as several adaptations of the "classic" chain suggest that the original form and even updated forms (e.g., including post-arrest care) might lack various essential links. Is the chain of survival thus a widely-known one-size-fits-all concept that should indeed be tailored to specific needs?

The impact on outcomes

Interestingly, only three publications assessed the impact of the chain of survival on any outcomes (clinical, educational, implementation-wise).[13,48,50] These studies are heavily biased, as assessed effects measured and attributed to the chain might not only arise from the chain of survival concept but rather from a change in clinical practice using the chain as a theoretical framework for actions. However, inducing such practical change may be one of the key assets of the chain of survival format. The aspect of the educational concept of the chain of survival does not really seem to play a role, at least not in the publications found. Further research on the potential of the chain of survival as an influencing factor towards important outcomes is needed – not only to scientifically back up the existing concept, but also to possibly further evolve it.

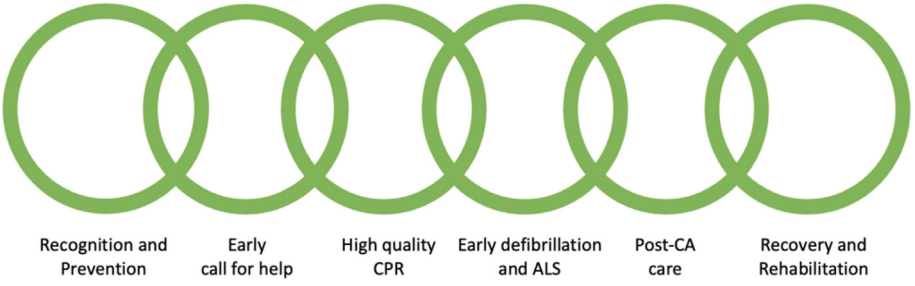

Fig. 2 – The basic chain of survival with six links. CPR = cardiopulmonary resuscitation; CA = cardiac arrest.

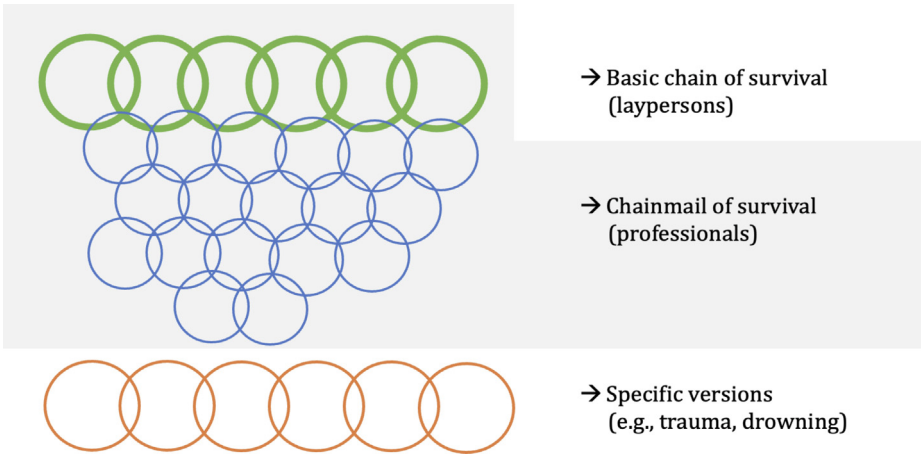

Fig. 3 – An example of the interaction of basic chain of survival, chainmail of survival, and potential specific versions for specific situations.

A suggestion on how to proceed

For now, the classic chain(s) of survival as currently used by the AHA[4] (Fig. 2) still seem(s) a sensible choice as a cognitive aid to convey the message of needed actions to save lives for education and awareness campaigns. However, also the AHA proposes four different sub-versions: One for OHCA, one for IHCA, and two for paediatric patients.[4] In summary, a "basic version" of the chain of survival" may be: (1) Recognition and Prevention, (2) Early call for help, (3) High quality CPR, (4) Early defibrillation and ALS, (5) Post cardiac arrest care, and (6) Recovery and Rehabilitation.

In view of all the presented modifications, very specific versions of the chain for very specific situations like drowning or trauma might be acceptable (if really needed), but a wide variety of chains should be avoided as the question arises what the added values for clinical, education, or implementation outcomes from variations of the chain of survival really are. The concept of the chainmail of survival[31,44] is open to include novel ideas (e.g., drones, community first responders, mobile phone application CPR alarms, etc.) and is adaptable to various resource settings, while staying in one format (however, it might be more valuable for professionals than for laypersons). As an adapted "one-size-fits-all concept", a multifaceted system (e.g., basic chain plus evolvements; Fig. 3) could be a way to go ahead. Naturally, its educational and implementation worth, as well as its parts and the impact on patient survival need to be studied to establish a solid evidence base. Also, the value of the chain of survival as a cognitive aid, especially for laypersons, must be evaluated. ILCOR as the international body on resuscitation could provide the basic structure of this framework based on evidence, and regional resuscitation councils could then provide a regional adaptation of the chain of survival for their implementation strategies.

Limitations

We did not have the opportunity to search grey literature and social media, as originally intended, because respective tools and resources were not available at the time. This means information could thus have been missed. Tools for assessing grey literature including social media should be developed and applied for such topics in the future. Moreover, even though the Task Force aimed at increased inclusiveness when conducting this review by inviting content experts from non-high resource settings, we recognize that the majority of collaborators works in high-resource settings, therefore potentially conveying biased views. Lastly, we wanted to provide the images of the described chains of survival and variations but could unfortunately not obtain the rights of a majority to reprint them in this publication. Therefore, we did not include respective images in order to not highlight certain ones while others could not be depicted.

Conclusion

There is a vast heterogeneity of chain of survival concepts published. Future research is warranted, especially into the concept's value concerning educational, implementation, and clinical outcomes.

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CRediT authorship contribution statement

Sebastian Schnaubelt: Writing – review & editing, Writing – original draft, Visualization, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Koenraad G Monsieurs:** Writing – review & editing, Supervision, Resources, Investigation, Data curation. **Nino Fijacko:** Writing – review & editing, Investigation, Data curation. **Christoph Veigl:** Writing – review & editing, Investigation, Data curation. **Zehra Al-Hilali:** Writing – review & editing, Investigation, Data curation. **Huba Atiq:** Writing – review & editing, Investigation, Data curation. **Blair L. Bigham:** Writing – review & editing, Investigation, Data curation. **Kathryn Eastwood:** Writing – review & editing, Investigation, Data curation. **Ying-Chih Ko:** Writing – review & editing, Investigation, Data curation. **Tasuku Matsuyama:** Writing – review & editing, Investigation,

Data curation. **Justine Athieno Odakha:** Writing – review & editing, Investigation, Data curation. **Alexander Olaussen:** Writing – review & editing, Investigation, Data curation. **Robert Greif:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization.

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. Supplementary material

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