Resuscitation 121 (2017) 201–214

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

ILCOR Summary Statement

2017 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations Summary☆

Theresa M. Olasveengen, Allan R. de Caen, Mary E. Mancini, Ian K. Maconochie, Richard Aickin, Dianne L. Atkins, Robert A. Berg, Robert M. Bingham, Steven C. Brooks, Maaret Castrén, Sung Phil Chung, Julie Considine, Thomaz Bittencourt Couto, Raffo Escalante, Raúl J. Gazmuri, Anne-Marie Guerguerian, Tetsuo Hatanaka, Rudolph W. Koster, Peter J. Kudenchuk, Eddy Lang, Swee Han Lim, Bo Løfgren, Peter A. Meaney, William H. Montgomery, Peter T. Morley, Laurie J. Morrison, Kevin J. Nation, Kee-Chong Ng, Vinay M. Nadkarni, Chika Nishiyama, Gabrielle Nuthall, Gene Yong-Kwang Ong, Gavin D. Perkins, Amelia G. Reis, Giuseppe Ristagno, Tetsuya Sakamoto, Michael R. Sayre, Stephen M. Schexnayder, Alfredo F. Sierra, Eunice M. Singletary, Naoki Shimizu, Michael A. Smyth, David Stanton, Janice A. Tijssen, Andrew Travers, Christian Vaillancourt, Patrick Van de Voorde, Mary Fran Hazinski, Jerry P. Nolan, On behalf of the ILCOR Collaborators

ARTICLE INFO

Keywords:
AHA Scientific Statements
Cardiopulmonary resuscitation
Heart massage

ABSTRACT

The International Liaison Committee on Resuscitation has initiated a near-continuous review of cardiopulmonary resuscitation science that replaces the previous 5-year cyclic batch-and-queue approach process. This is the first of an annual series of International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations summary articles that will include the cardiopulmonary resuscitation science reviewed by the International Liaison Committee on Resuscitation in the previous year. The review this year includes 5 basic life support and 1 paediatric Consensuses on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Each of these includes a summary of the science and its quality based on Grading of Recommendations, Assessment, Development, and Evaluation criteria and treatment recommendations. Insights into the deliberations of the International Liaison Committee on Resuscitation task force members are provided in Values and Preferences sections. Finally, the task force members have prioritised and listed the top 3 knowledge gaps for each population, intervention, comparator, and outcome question.

Until recently, the International Liaison Committee on Resuscitation (ILCOR) cardiopulmonary resuscitation (CPR) science review process has been undertaken in 5-year cycles, the last being published in 2015.[1,2] This batch-and-queue approach has the advantage of enabling a well-planned and systematic update of guidelines and training materials, but it could potentially delay the implementation of new effective treatments. In 2016, ILCOR adopted a new process that would enable a near-continuous review of resuscitation science by using task force–prioritised population, intervention, comparator, and outcome (PICO) questions. There will be 2 distinct pathways for evidence evaluation. Knowledge

☆ This article has been copublished in *Circulation: Cardiovascular Quality and Outcomes*.

https://doi.org/10.1016/j.resuscitation.2017.10.021

synthesis units (KSUs), organisations with expertise in searching scientific databases and performing systematic reviews and meta-analyses, will address PICOs that are large and complicated or topics for which several PICOs can be grouped together and addressed through sensitivity or subgroup analyses. Contracted systematic reviewers will undertake simple systematic reviews involving typically single PICO questions. Both pathways involve content experts, and critical steps during evidence evaluation are discussed with relevant task forces when needed.

The Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) process that was adopted for the ILCOR "2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations" (CoSTR) will also be used for the continuous review of CPR science.[3] In the GRADE approach, the quality of evidence supporting intervention effects (defined by the PICO question) is rated as high, moderate, low, or very low. Randomised controlled trials (RCTs) start as high-quality evidence, and observational studies start as low-quality evidence. Five factors may lead to downgrading of the quality of evidence, and 3 factors may enable an upgrade of the quality of evidence (Table).[4–9] The quality assessments for each outcome are summarised in GRADE evidence profile tables, which also include a summary of findings in the form of the numbers of patients, the relative risk (RR), and an indication of the absolute risk (described as the risk difference [RD]).

This is the first of a series of annual ILCOR CoSTR summary articles that will include the CPR science reviewed by ILCOR in the previous year. The review this year includes 5 basic life support (BLS) CoSTRs and 1 paediatric CoSTR. The CoSTRs were produced after a systematic review by the KSU at St. Michael's Hospital, Toronto, ON, Canada, in collaboration with ILCOR content experts and members of the ILCOR BLS and Paediatric Task Forces. All the evidence profile tables and meta-analyses were produced by the KSU and reviewed by ILCOR BLS and Paediatric Task Forces. The CoSTRs have been subjected to rigorous evaluation, peer review, and public comment. We anticipate that by 2018, ≈20 PICO questions will be addressed per year, and each question will generate a draft CoSTR that will be published on the ILCOR website.[10] The draft CoSTRs published online will provide the data for the annual CoSTR summary article that will be published each year. The summary article differs in several respects from the draft CoSTRs published on the ILCOR website: The language used to describe the science is not restricted to standard GRADE terminology, which makes it more accessible to a wider audience; the values and preferences have been expanded to provide greater insight into the rationale for treatment recommendations, particularly when high-quality evidence is lacking; and the top 3 knowledge gaps for each topic have been prioritised and ranked by the task force members.

Table GRADE Quality Assessment Criteria

Study Design	Quality of Evidence	Lower if	Higher if
Randomised trial Observational study	High Moderate Low Very low	Risk of bias Inconsistency Indirectness Imprecision Publication bias	Large effect Dose response All plausible confounding: would reduce a demonstrated effect or would suggest a spurious effect when results show no effect

The CoSTRs are based on the data summarised in the GRADE evidence profile tables for each of the key outcomes for each of the clinical scenarios. The pertinent outcome data are listed for each statement as RR (with 95% confidence interval [CI]) and RD (with 95% CI). The RD is the absolute difference between the risks and is calculated by subtracting the risk in the control group from the risk in the intervention group. This absolute effect enables a more clinically useful assessment of the magnitude of the effect of an intervention and enables calculation of the number needed to treat (=1/RD).

CPR Strategies: Background

One of the primary measures taken to improve survival after cardiac arrest has been focused efforts to improve the quality of CPR. Although the impact of high-quality chest compressions has been studied extensively,[11–14] the role of ventilation and oxygenation is less clear. Efforts to simplify resuscitation by delaying ventilation or by providing passive oxygenation have been implemented for both lay and professional rescuers. These strategies have been consistently associated with increased bystander CPR rates and fewer pauses in chest compressions, but effects on survival have been less clear.[15–18]

During the development of the 2015 CoSTR, several PICO questions were dedicated to reviewing evidence of continuous chest compression strategies for both lay and professional rescuers in various populations (adult, paediatric) and for various settings (in hospital, out of hospital).[19–22] Shortly after these reviews were completed, a 23711-patient RCT evaluating the effectiveness of continuous chest compressions in the emergency medical services (EMS) setting was published.[23] In parallel, developments of large national and regional registries are continually providing new insights into the epidemiology of cardiac arrest and bystander CPR.[24] These emerging publications generated an urgent need to review all available evidence on continuous compression strategies to provide updated evidence evaluations that included the latest science available. The systematic review and meta-analysis of this topic undertaken by St. Michael's Hospital KSU and ILCOR has been published separately.[25]

The Population, Intervention, Comparator, Outcome, Study Designs, and Time Frame

The following was used by St. Michael's Hospital KSU when undertaking the systematic review:

- Population: Patients of all ages (eg, neonates, children, adults) with cardiac arrest from any cause and across all settings (in hospital and out of hospital) were included. Studies that included animals were not eligible.
- Intervention: All manual CPR methods, including compression-only CPR, continuous compression CPR, and CPR with different compression-to-ventilation (CV) ratios, were used. Compression-only CPR included compressions with no ventilations; continuous compression CPR included compressions with asynchronous ventilations or minimally interrupted cardiac resuscitation. Studies that mentioned the use of a mechanical device during CPR were considered only if the same device was used across all relevant intervention arms and would therefore not confound the observed effect.
- Comparators: Studies had to compare at least 2 different CPR methods from the eligible interventions; studies without a comparator were excluded.
- Outcomes: The primary outcome was favourable neurological outcomes, measured by cerebral performance or a modified Rankin Scale. Secondary outcomes were survival, return of spontaneous circulation, and quality of life.
- Study designs: RCTs and nonrandomised studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies) were eligible for inclusion. Study designs with-

out a comparator group (eg, case series, cross-sectional studies), reviews, and pooled analyses were excluded.
- Time frame: Published studies in English searched on January 15, 2016, were included.

Dispatch-Assisted Compression-Only CPR Compared With Dispatch-Assisted Conventional CPR (Adults): Consensus on Science

Dispatch-assisted compression-only CPR was compared with dispatch-assisted conventional CPR (ratio of 15 compressions to 2 ventilations) in 1 RCT that generated low-quality evidence for favourable neurological function.[16] The quality of evidence was downgraded for serious imprecision because only 2 of the 3 sites provided data on neurological outcome. In this study, instructions to give continuous chest compressions had no demonstrable benefit for favourable neurological function (RR, 1.25 [95% CI, 0.94–1.66]; RD, 2.86 percentage points [95% CI, −0.80 to 6.53]) compared with instructions to give compressions and ventilations at a ratio of 15:2.

Dispatch-assisted compression-only CPR compared with dispatch-assisted conventional CPR (ratio of 15 compressions to 2 ventilations) in 3 RCTs provided low-quality evidence for the critical outcome of survival to hospital discharge.[15–17] The quality of evidence for these studies was downgraded because of serious risk of bias: All 3 studies excluded patients after randomisation and included an intervention that could not be blinded, and in at least 1 study, many outcome data were missing.[17] In a previously published meta-analysis of these studies, there appeared to be a small benefit in survival to hospital discharge in favour of the group instructed to give continuous chest compressions compared with the group instructed to give compressions and ventilations at a ratio of 15:2 (RR, 1.22 [95% CI, 1.01–1.46]; RD, 2.4 percentage points [95% CI, 0.1–4.9]; fixed-effect model; P=0.04).[26] This meta-analysis used survival to hospital discharge for all 3 studies,[15–17] although the Swenson study was missing 55% of these outcome data. In a meta-analysis using a random-effect model to combine survival to hospital discharge[15,16] and 30-day survival[17] outcomes to capture the maximum amount of data, survival was no longer significantly different between the 2 groups. Continuous chest compressions had an RR for survival of 1.20 (95% CI, 1.00–1.45; RD, 1.88 percentage points [95% CI, −0.05 to 3.82]) compared with conventional 15:2 CPR.

Treatment Recommendation

We recommend that dispatchers provide chest compression–only CPR instructions to callers for adults with suspected out-of-hospital cardiac arrest (OHCA) (strong recommendation, low-quality evidence).

Values and Preferences

In making these recommendations, we recognise that the evidence in support of these recommendations comes from randomised trials of variable quality performed at a time when the ratio of chest compressions to ventilations was 15:2, which leads to greater interruptions to chest compressions than the currently recommended ratio of 30:2. However, the signal from every trial is consistently in favour of telephone CPR protocols that use a compression-only CPR instruction set. Reviewing the totality of available evidence and considering current common practice, training, and quality assurance experiences, the BLS Task Force has kept the strong recommendation for compression-only CPR for dispatch-assisted CPR despite low-quality evidence. In making these recommendations, we placed a higher value on the initiation of bystander compressions and a lower value on possible harms of delayed ventilation. The task force recognises that there are many unanswered questions when balancing possible benefits and harms from bystander ventilation. Most notably, although some cardiac arrest pathogeneses (eg, asphyxial cardiac arrest) might be dependent on early ventilation to increase survival, bystanders' ability to learn how to perform mouth-to-mouth ventilations over the phone is not known. Possible harmful effects of incorrectly performed ventilations (gastric inflation) and fewer compressions performed before ambulance arrival because of more complex instructions and pauses for ventilation were weighted more heavily than potential benefits from early ventilation.

This document refers to dispatch-assisted CPR. In adopting this terminology, we acknowledge that the dispatching of emergency medical resources is a limited description of the tasks performed by multiprofessional teams working in emergency medical dispatch centres, and perhaps more suitable options are being used worldwide. They include telecommunicators, ambulance communication officers, emergency medical communicators, and call handlers, as well as other terms more closely related to their actual task description.

Knowledge Gaps

Several knowledge gaps were identified in the review of this topic. A more comprehensive list has been posted on the ILCOR website.[10] The BLS Task Force ranked the knowledge gaps in priority order, and the top 3 are the following:

1. What is the optimal instruction sequence for coaching callers in dispatch-assisted CPR?
2. What are the identifying key words used by callers that are associated with cardiac arrest?
3. What is the impact of dispatch-assisted CPR instructions on cardiac arrests from noncardiac causes such as drowning, trauma, or asphyxia in adult and paediatric patients?

Bystander Compression-Only CPR Compared With Bystander CPR Using Compressions and Ventilations (Adults): Consensus on Science

Bystander CPR using chest compressions only was compared with bystander CPR using a CV ratio of 15:2 or 30:2 in 6 cohort studies that generated very-low-quality evidence for the critical outcome of favourable neurological function.[24,27–31] In a meta-analysis of 2 studies, there was no significant difference in favourable neurological function in patients who received compression-only CPR compared with patients who received CPR at a CV ratio of 15:2 (RR, 1.34 [95% CI, 0.82–2.20]; RD, 0.51 percentage points [95% CI, −2.16 to 3.18]).[27,29] The quality of evidence was downgraded for serious indirectness and imprecision because of varying results across studies, because the control group had a different CV ratio from the intervention group, and because there was variable postarrest care. In a meta-analysis of 3 studies, there was no significant difference in favourable neurological function in patients who received compression-only CPR compared with patients who received compressions and ventilations during a period when the CV ratio changed from 15:2 to 30:2 (RR, 1.12 [95% CI, 0.71–1.77]; RD, 0.28 percentage points [95% CI, −2.33 to 2.89]).[28,30,31] The quality of evidence was downgraded for serious indirectness and imprecision because the control group had a different CV ratio from the intervention group and there was variable postarrest care. One study examined the influence of nationwide dissemination of compression-only CPR recommendations for lay rescuers and showed that, although bystander CPR rates and nationwide survival improved, patients who received compression-only CPR had lower survival compared with patients who received chest compressions and ventilations at a CV ratio of 30:2 (RR, 0.72 [95% CI, 0.69–0.76]; RD, −0.74 percentage points [95% CI, −0.85 to 0.63]).[24] The quality of evidence was downgraded for serious indirectness because the study did not directly compare compression-only CPR with CPR with chest compressions and ventilations but rather compared compression-only and CPR with chest compressions and ventilations with no CPR. The evidence was also considered indirect because multiple aspects of resuscitation were likely to have changed over time in this before-and-after study.

Bystander CPR using compression-only CPR was compared with bystander CPR using a CV ratio of 15:2 or 30:2 in 7 cohort studies that generated very-low-quality evidence for the critical outcome of survival.[24,27,29,32–35] In a meta-analysis of 6 studies, there was no significant difference in survival in patients who received compression-only CPR compared with patients who received CPR at a CV ratio of 15:2 (RR, 0.88 [95% CI, 0.74–1.04]; RD, −0.83 percentage points [95% CI, −1.85 to 0.19]).[27,29,32–35] The quality of evidence was downgraded for serious risk of bias and indirectness. Risk of bias was related to the comparability of the cohorts because the majority did not adjust for potential confounders. The studies were also downgraded for indirectness because they either were investigating CPR guideline changes or did not explicitly report the CV ratio among included cases. In 1 study, patients receiving compression-only CPR had worse survival compared with patients who received CPR at a CV ratio of 30:2 (RR, 0.75 [95% CI, 0.73–0.78]; RD, −1.42 percentage points [95% CI, −1.58 to −1.25]).[24] The quality of evidence was downgraded for serious indirectness as described earlier. In a meta-analysis of 3 observational studies,[28,30,31] there was no significant difference in survival when patients who received compression-only CPR were compared with patients who received CPR during a period when the CV ratio changed from 15:2 to 30:2 (RR, 1.16 [95% CI, 0.64–2.09]; RD, 1.27 percentage points [95% CI, −3.70 to 6.23]). The quality of evidence was downgraded for serious inconsistency, indirectness, and imprecision as described earlier.

Treatment Recommendations

We continue to recommend that bystanders perform chest compressions for all patients in cardiac arrest (good practice statement). In the 2015 CoSTR, this was cited as a strong recommendation but based on very-low-quality evidence.[19,20]

We suggest that bystanders who are trained, able, and willing to give rescue breaths and chest compressions do so for all adult patients in cardiac arrest (weak recommendation, very-low-quality evidence).

Values and Preferences

In making these recommendations, the task force placed high value on the 2010 and 2015 CoSTRs that showed that rescuers should perform chest compressions for all patients in cardiac arrest.[19,20,36,37] Given that the 2017 systematic review did not seek data comparing any CPR with no CPR and in keeping with GRADE recommendations, our recommendation for performing chest compressions for all patients in cardiac arrest has been cited as a good practice statement (see Appendixes 1 and 2).[38] We also placed high value on the advantage derived from the simplicity of teaching or providing instructions for compression-only CPR. This recommendation reflects the value placed on the data that indicate no apparent downside in patients with true arrest with similar survival rates from adult cardiac arrests of cardiac origin both with and without ventilations.[39,40] We also acknowledged the potential additional benefits of CPR with compressions and ventilations when delivered by trained laypeople, particularly in settings where EMS response intervals are long or when the cause of cardiac arrest is asphyxia.

Knowledge Gaps

Several knowledge gaps were identified in the review of this topic. A more comprehensive list has been posted on the ILCOR website.[10] The BLS Task Force ranked the knowledge gaps in priority order, and the top 3 are listed here:

1. The effect of delayed ventilation versus 30:2 high-quality CPR.
2. The impact of continuous chest compressions on outcomes for cardiac arrests from noncardiac causes such as drowning, trauma, or asphyxia in adult and paediatric patients.
3. The ability of bystanders to perform correct mouth-to-mouth ventilations.

EMS-Delivered CPR: Consensus on Science

High-quality CPR includes minimal interruptions to chest compressions. Three distinct techniques are used by EMS to deliver continuous chest compression CPR during OHCA: (1) continuous chest compressions with positive-pressure ventilation (PPV) of the lungs with a bag-mask device typically at a rate of 10 breaths per minute, (2) continuous chest compressions and PPV of the lungs via a tracheal tube or supraglottic airway, and (3) continuous chest compressions with passive oxygenation typically with an oropharyngeal airway and simple oxygen mask (a strategy sometimes referred to as minimally interrupted cardiac resuscitation). Studies involving these techniques have typically delayed insertion of an advanced airway until after return of spontaneous circulation or 3 cycles of CPR.

For the critical outcome of favourable neurological function, we identified high-quality evidence from 1 RCT[23] and very-low-quality evidence from 2 cohort studies.[18,41] In the RCT, patients who were randomised to PPV delivered with a bag-mask device without pausing chest compressions had no demonstrable benefit for favourable neurological function (RR, 0.92 [95% CI, 0.84–1.00]; RD, −0.65 percentage points [95% CI, −1.31 to 0.02]) compared with patients randomised to conventional CPR with a CV ratio of 30:2.[23] In 1 cohort study, patients who received continuous chest compressions and passive ventilation for 3 cycles had improved favourable neurological function (RR, 2.58 [95% CI, 1.5–4.47]; RD, 24.11 percentage points [95% CI, 11.58–36.63]) compared with those who received compressions and ventilations at a time when the CV ratio changed from 15:2 to 30:2.[41] The quality of evidence was downgraded for serious risk of bias and indirectness. Risk of bias included moderate risk that the continuous chest compression cohort was not representative and high risk that there were confounding factors between the cohorts for which there was no adjustment. The study was considered indirect because of its before-and-after design including a period with changing guidelines. In the other cohort study,[18] minimally interrupted cardiac resuscitation (initial series of 3 cycles of 200 uninterrupted chest compressions, passive ventilation, before-and-after rhythm analysis with shock if appropriate) in patients with witnessed shockable cardiac arrest had no demonstrable benefit for favourable neurological function (RR, 0.81 [95% CI, 0.57–1.13]; RD, −11.30 percentage points [95% CI, −28.48 to 5.87]) compared with conventional CPR (mixture of CV ratios of 15:2 and 30:2). The quality of evidence was downgraded for serious risk of bias, indirectness, and imprecision. Risk of bias included moderate risk that the continuous chest compression cohort was not representative and unclear risk of inadequate follow-up. The study was considered indirect because of its before-and-after design including a period with changing guidelines and imprecise because the CIs for RD crossed from appreciable harm (0.75) to appreciable benefit (1.25).

For the critical outcome of survival, we identified high-quality evidence from 1 RCT[23] and very-low-quality evidence from 1 cohort study.[18] In the RCT, there was no significant difference in survival to discharge of patients randomised to continuous chest compressions compared with patients randomised to conventional CPR with a CV ratio of 30:2 (RR, 0.92 [95% CI, 0.85–1.00]; RD, −0.76 percentage points [95% CI, −1.51 to 0.02]).[23] In the cohort study,[18] patients with witnessed shockable cardiac arrest who received minimally interrupted cardiac resuscitation had improved survival (RR, 2.37 [95% CI, 1.69–3.31]; RD, 5.24 percentage points [95% CI, 2.88–7.60]) compared with conventional CPR using a mixture of 30:2 and 15:2 CV ratios. The quality of evidence was downgraded for serious indirectness and imprecision as described earlier.

Treatment Recommendations

We recommend that EMS providers perform CPR with 30 compressions to 2 ventilations or continuous chest compressions with PPV delivered without pausing chest compressions until a tracheal tube or supraglottic device has been placed (strong recommendation, high-quality evidence).

We suggest that when EMS systems have adopted minimally interrupted cardiac resuscitation, this strategy is a reasonable alternative to conventional CPR for witnessed shockable OHCA (weak recommendation, very-low-quality evidence).

Values and Preferences

In making these recommendations, the task force took into consideration that although there was relative homogeneity in the body of evidence around EMS continuous chest compressions and adjunctive therapies (eg, bundles of care in the community such as improved bystander CPR strategies and hospital systems of care such as transfers to resuscitation centres), there was heterogeneity in the continuous CPR ventilation strategies (ie, passive versus PPV strategies) and in the comparator groups. The recommendations reflect high-quality evidence for the safety of CPR with compressions and ventilations (CV ratio, 30:2) by EMS providers while acknowledging the lack of data supporting superior functional or survival outcomes. The task force also placed a relatively high value on the importance of providing high-quality chest compressions and simplifying resuscitation logistics for EMS systems and noted the support for the clinical benefit of bundles of care involving minimally interrupted cardiac resuscitation. In making a weak recommendation in support of systems that have implemented minimally interrupted cardiac resuscitation, the task force also acknowledges the lack of RCTs evaluating passive oxygenation strategies such as those described in minimally interrupted cardiac resuscitation.

Knowledge Gaps

Several knowledge gaps were identified in the review of this topic. A more comprehensive list has been posted on the ILCOR website.[10] The BLS Task Force ranked the knowledge gaps in priority order, and the top 3 follow:

1. What is the effect of delayed ventilation versus 30:2 high-quality CPR?
2. Which elements of the bundled care (compressions, ventilations, delayed defibrillation) are most important?
3. How effective is passive oxygen insufflation (applying a flow of oxygen via a face mask or a supraglottic airway but without PPV)?

In-Hospital CPR: Consensus on Science

Only 1 cohort study evaluating the effect of continuous chest compressions in the in-hospital setting was identified.[42] In this study, PPV without interruption of chest compressions after tracheal intubation was compared with interruption of chest compressions for 1 ventilation after every fifth chest compression (a CV ratio of 5:1) among patients admitted to a hospital emergency department after OHCA. Chest compressions were delivered by a mechanical device known as the Thumper Mechanical CPR Machine (Michigan Instruments, Grand Rapids, MI) in all patients, a device that is not commonly used clinically and that delivered different average compression rates (70 versus 100 per minute) between the study periods. The study compared continuous chest compressions and ventilations delivered after every 10th compression (without pausing compressions) with a 5:1 CV ratio (with pauses for ventilation) that resulted in more frequent pauses in compressions and higher overall ventilation rates than the conventional 30:2 CV ratio recommended by the 2015 CoSTR.[19,20] It was conducted with a before-and-after design that, although adjusted for demographic and cardiac arrest characteristics, did not account for potential temporal differences in resuscitation efficiencies between study periods.

Very-low-quality evidence was identified for the critical outcome of favourable neurological function.[42] There was no difference in favourable neurological outcome between the uninterrupted 10:1 CPR and interrupted 5:1 CPR cohorts (RR, 1.18 [95% CI, 0.32–4.35]; RD, 0.29 percentage points [95% CI, −2.05 to 2.64]). The quality of evidence was downgraded to very serious imprecision because the CIs for RD crossed from appreciable harm (0.75) to appreciable benefit (1.25).

Low-quality evidence was identified for the critical outcome of survival.[42] The uninterrupted 10:1 CPR cohort had a higher survival rate to hospital discharge compared with the interrupted 5:1 CPR cohort (RR, 2.38 [95% CI, 1.22–4.65]; RD, 5.86 percentage points [95% CI, 1.19–10.53]).

Treatment Recommendation

Whenever tracheal intubation or a supraglottic airway is achieved during in-hospital CPR, we suggest that providers perform continuous compressions with PPV delivered without pausing chest compressions (weak recommendation, very-low-quality evidence).

Values and Preferences

In making this recommendation, the task force noted that there is no prospective study of in-hospital CPR that compares delivery of ventilations during continuous manual chest compressions with ventilations delivered during pauses in manual chest compressions. The task force placed value in that delivering continuous chest compressions is a common practice in many settings after tracheal intubation or placement of a supraglottic airway. The only study to have addressed this specific question in an in-hospital setting has limited applicability in that it was performed after OHCA and in the context of mechanical chest compressions, along with other limitations. However, the findings of this study support the treatment recommendation.

Knowledge Gaps

Several knowledge gaps were identified in the review of this topic. A more comprehensive list has been posted on the ILCOR website.[10] The BLS Task Force ranked the knowledge gaps in priority order, and the top 3 are as follows:

1. No prospective study of in-hospital CPR compares delivery of ventilations during continuous manual chest compressions with ventilations delivered during pauses in manual chest compressions.
2. What is the effect of delayed ventilation versus 30:2 high-quality CPR?
3. What is the optimal method for ensuring a patent airway?

Chest CV Ratio (Adults): Consensus on Science

The 30:2 CV ratio was compared with a different CV ratio in 2 observational cohort studies that generated very-low-quality evidence for the critical outcome of favourable neurological function.[43,44] In a meta-analysis of these studies, the 30:2 CV ratio demonstrated benefit for favourable neurological function (RR, 1.34 [95% CI, 1.02–1.76]; RD, 1.72 percentage points [95% CI, 0.52–2.91]) compared with the CV ratio of 15:2. The quality of evidence was downgraded for serious indirectness because these studies were before-and-after investigations that evaluated the bundle-of-care interventions implemented after the "2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations,"[45,46] in which the change in CV ratio was just 1 aspect.

Seven observational cohort studies provided very-low-quality evidence for the critical outcome of survival.[43,44,47–51] The quality of evidence was downgraded for serious indirectness because the CV ratio was not the only aspect evaluated in these studies. In a meta-analysis of 6 cohort studies, the survival rate was higher in the group of patients who received 30:2 CPR compared with the group who received 15:2 CPR (RR, 1.37 [95% CI, 1.19–1.59]; RD, 2.48 percentage points [95% CI, 1.57–3.38]).[43,44,47,49–51] One retrospective cohort showed improved survival with the 50:2 CV ratio compared with the 15:2 ratio (RR, 1.96 [95% CI, 1.28–2.99]; RD, 21.48 percentage points [95% CI, 6.90–36.06]).[48] The quality of evidence was downgraded for serious risk of bias and indirectness. Risk of bias included high risk that the cohorts were not comparable on the basis of design or analysis and moderate risk of inadequate follow-up. The study was also considered indirect because of its before-and-after design potentially evaluating several changes to practice.

Treatment Recommendation

We suggest a CV ratio of 30:2 compared with any other CV ratio in patients with cardiac arrest (weak recommendation, very-low-quality evidence).

Values and Preferences

In making this recommendation, the task force acknowledged that there would likely be substantial resource implications (eg, reprogramming, retraining) associated with a change in recommendation related to the CV ratio. In the absence of any data addressing the critical outcomes, the task force placed a high value on maintaining consistency with the 2005, 2010, and 2015 CoSTRs.[19,20,36,37,45,46] We also placed high value on findings that suggest that a bundle of care (which included a CV ratio of 30:2) resulted in more lives being saved.

Knowledge Gaps

Several knowledge gaps were identified in the review of this topic. A more comprehensive list has been posted on the ILCOR website.[10] The BLS Task Force ranked the knowledge gaps in priority order, and the top 3 follow:

1. The possible benefit of higher CV ratios (more compressions per ventilations).
2. The ability of CPR providers to deliver 2 effective ventilations during the short pause in chest compressions during CPR.
3. Is there a ratio-dependent critical volume of air movement required to maintain effectiveness?

Bystander CPR for Paediatric OHCA: Consensus on Science

A recent systematic review compared outcomes associated with bystander compression-only CPR with those of bystander CPR that included chest compressions plus ventilation for paediatric OHCA.[25] The review identified 2 large observational cohort studies, both using data from Japan's nationwide All-Japan Utstein OHCA registry.[52,53] This large mandatory registry includes all cardiac arrests in people of all ages in Japan and both cardiac and non-cardiac (eg, trauma, hanging, drowning, drug overdose, asphyxia, respiratory diseases, cerebrovascular diseases, malignant tumours) causes of arrest. As of 2017, it contains data from >1 million cardiac arrests.

The Kitamura et al[52] study includes 5170 events in children $\leq$17 years of age, including 2439 events in which bystander CPR was performed, captured from 2005 through 2007. At the time of the study, resuscitation guidelines in Japan were transitioning from a CV ratio of 15:2 to 30:2 for paediatric OHCA. The Goto et al[53] study includes 5056 events in children $\ll$18 years of age, including 2722 events in which bystander CPR was performed, captured from 2008 through 2010. At the time of the study, paediatric CPR guidelines in Japan recommended CPR that included ventilation with a CV ratio of 30:2. In addition, national implementation of a dispatch-assisted CPR program was occurring.

The quality of evidence was downgraded to very low for the critical outcome of favourable neurological function (Paediatric Cerebral Performance Category [PCPC] 1 or 2) at 1 month.[52,53] The quality of evidence for these studies was downgraded because of serious risk of bias (eg, potential variability between comparison groups, single-country/healthcare system registry, variability in protocols among fire/EMS departments), serious indirectness (ie, the CV ratio provided was not specifically described in the publications and had to be deduced from the description of the guidelines and recommendations that were reported to be used at the time of data collection), and serious imprecision (wide CIs). In the first study, in all children, survival with favourable neurological function (PCPC 1 or 2) was less likely among children receiving chest compression–only CPR (RR, 0.46 [95% CI, 0.29–0.73]; RD, 3.02 percentage points [95% CI, 1.47–4.57]).[52] After further subgroup analysis by age, patients 1 to 17 years of age with bystander chest compression–only CPR had worse outcomes (RR, 0.46 [95% CI, 0.28–0.75]; RD, 4.34 percentage points [95% CI, 1.95–6.73]). In infants, outcome was uniformly poor, and there was no demonstrable difference in favourable neurological function whether bystanders provided chest compression–only CPR or CPR with ventilation (RR, 0.39 [95% CI, 0.11–1.36]; RD, 1.31 percentage points [95% CI, −0.17 to 2.80]). The second study did not report results divided by age subgroups but identified fewer patients overall with favourable neurological function (PCPC 1 or 2) in the chest compression–only CPR group than in those receiving CPR with a CV ratio of 30:2, (RR, 0.45 [95% CI, 0.31–0.66]; RD, 3.30 percentage points [95% CI, 1.71–4.88]).[53] These data were not published in the original article but were provided via e-mail from the corresponding author of the study (Y. Goto, MD, PhD, personal e-mail communication, unpublished data, May 2, 2014).

The quality of evidence was very low for the critical outcome of survival to 1 month.[52,53] The quality of evidence for these studies was downgraded because of serious risk of bias, serious indirectness, and serious imprecision (see reasons for downgrading given previously). In the Kitamura et al[52] study, outcomes were worse for all children who received bystander chest compression–only CPR compared with those who received CPR with ventilation (RR, 0.76 [95% CI, 0.60–0.97]; RD, 2.98 percentage points [95% CI, 0.45–5.51]). After further subgroup analysis by age, patients 1 to 17 years of age who received chest compression–only CPR had worse outcomes (RR, 0.70 [95% CI, 0.53–0.93]; RD, 4.74 percentage points [95% CI, 1.17–8.31]). In infants, there was no demonstrable difference in survival to 1 month (RR, 0.90 [95% CI, 0.56–1.45]; RD, 0.74 percentage points [95% CI, −2.61 to 4.09]). In the Goto et al[53] study, survival was worse among children who received chest compression–only CPR compared with those who received CPR with ventilation (RR, 0.56 [95% CI, 0.45–0.69]; RD, 7.04 percentage points [95% CI, 4.50–9.58]). There was no subgroup analysis for different ages in this study.

Treatment Recommendations

We suggest that bystanders provide CPR with ventilation for infants and children ≪18 years of age with OHCA (weak recommendation, very-low-quality evidence).

We continue to recommend that if bystanders cannot provide rescue breaths as part of CPR for infants and children ≪18 years of age with OHCA, they should at least provide chest compressions (good practice statement). In the 2015 CoSTR, this was cited as a strong recommendation but based on very-low-quality evidence.[21,22]

Additional Science Published Since the Systematic Review Was Completed

After the systematic review was completed, 2 additional relevant observational studies were published,[54,55] and they have informed the task force decision in its treatment recommendation.

Very-low-quality evidence was identified for the critical outcome of favourable neurological function (PCPC 1 or 2) at hospital discharge.[54] The GRADE quality for this study was downgraded for serious risk of bias (observational study with possible variability between comparison groups) and serious indirectness (specific CPR CV ratio not listed) from 1 cohort study. This study is from a voluntary American OHCA registry of nontraumatic cardiac arrest that represents a catchment area of >90 million people in 37 states. This study included 3900 events captured from 2013 through 2015 and compared the outcomes of children receiving either bystander chest compression–only CPR or bystander CPR with ventilation for the 1411 children for whom data were available on the type of CPR provided. Data from Figure 4 of this study indicate that there was no difference in favourable neurological function when infants who received chest compression–only CPR were compared with those who received CPR with ventilation (P=0.083), as well as no difference among children (1–17 years of age) who received chest compression–only CPR compared with those who received CPR with ventilation (P=0.117).[54]

Very-low-quality evidence has been identified for the critical outcome of favourable neurological function (PCPC 1 or 2) at 1 month.[55] This study was another observational study from the all-Japan registry. The level of evidence for this study was downgraded for serious risk of bias (observational study with possible variability between comparison groups), serious indirectness (specific CPR CV ratio not listed), and very serious imprecision (very wide CI). This Japanese OHCA registry study (including traumatic cardiac arrest) reported 2157 events in children >1 year (ie, no infants) and ≪18 years of age, captured from 2011 through 2012, and compared the outcomes of children receiving either bystander chest compression–only CPR or bystander CPR with ventilation for the 1150 children for whom data were available on the type of CPR provided. The study was performed at a time when Japan CPR guidelines recommended a CV ratio of 30:2, and an established national dispatch-assisted CPR protocol existed. Favourable neurological function was no different among children who received chest compression–only CPR and those who received CPR with ventilation (adjusted odds ratio, 1.52 [95% CI, 0.93–2.49]).

Very-low-quality evidence has been identified for the critical outcome of survival to 1 month.[55] The quality of evidence for this cohort study was downgraded for serious risk of bias, serious indirectness, and very serious imprecision (see explanations given previously). In this study, 1-month survival in children (age, 1–18 years) was no different whether they received chest compression–only CPR or CPR with ventilation (adjusted odds ratio, 1.38 [95% CI, 0.98–1.96]).

Very-low-quality evidence has been identified for the critical outcome of survival to hospital discharge.[54] The quality of evidence for this cohort study was downgraded for serious risk of bias (observational study with possible variability between comparison groups). In infants with OHCA, survival to hospital discharge was worse in those receiving chest compression–only CPR compared with those receiving CPR with ventilation (P=0.002). Conversely, for children ≥1 year of age, there was no difference in survival to hospital discharge in a comparison of those who received bystander chest compression–only CPR and those who received CPR with ventilation (P=0.258).

Values and Preferences

Bystander CPR improves survival, and CPR treatment recommendations should strive to enhance ease of CPR implementation and CPR effectiveness. Most paediatric cardiac arrests are asphyxial in origin, so effective CPR is likely to require ventilation in addition to chest compressions. In making these recommendations, the task force placed a higher value on the importance of rescue breaths as part of paediatric CPR over a strategy that deemphasises ventilation to simplify CPR instructions and skills. The 2 (observational) articles published since the completion of the systematic review suggest that survival and neurological outcome may not differ among children (ie, ≥1 year of age) who receive bystander compression-only CPR or CPR with ventilation.[54,55] This conclusion differs from previous evidence that suggested the superiority of CPR with ventilation for paediatric patients of all ages with OHCA.[21,22,56] Available data are now inconsistent and somewhat contradictory for the comparison of bystander compression-only CPR and CPR with ventilation for infant (≪1 year of age) OHCA. These discrepancies in findings, especially those coming from the more recent publications, helped inform task force decisions with respect to the bystander CPR with ventilation versus compression-only CPR treatment recommendations and explain the rationale behind the task force's decision to downgrade the strength of the treatment recommendation to the weaker terminology of *suggests* instead of the stronger term *recommends*. This relative clinical equipoise should stimulate the development of prospective clinical trials to definitively determine the optimal bystander CPR technique for infants (≪1 year of age) and children (≥1 year of age).

Despite the availability of only very-low-quality evidence (analysed as part of the 2015 ILCOR evidence evaluation process), the task force unanimously agreed to reiterate the 2015 strong treatment recommendation for providing any CPR (including compression-only CPR) over no CPR for paediatric OHCA because the potential benefit outweighs any potential harm. Given that the systematic review did not seek data comparing any CPR with no CPR and in keeping with GRADE recommendations, our recommendation has been cited as a good practice statement (see Appendixes 1 and 2).[38]

Knowledge Gaps

In order of priority, the top knowledge gaps for this topic are as follows:

1. More high-quality studies are needed to compare compression-only CPR and CPR with ventilation for infants and children with OHCA.
2. Data are needed from other resuscitation registries that will enable comparison of the role of ventilation with CPR because this varies worldwide, largely on the basis of differences in local resuscitation council guidelines. This should also include subgroup analysis of different patient ages (eg, infancy, 1–8 years, >8 years) and causes of cardiac arrest.
3. Can telephone dispatchers coach bystanders to provide effective rescue breaths/CPR with ventilation for infants and children?

Acknowledgements

The authors thank the ILCOR Collaborators for their contributions to this document: Karl B. Kern, MD, FAHA; Koenraad G. Monsieurs, MD, PhD, FERC, FAHA; Robert W. Neumar, MD, PhD, FAHA; Clifton W. Callaway, MD, PhD; and Tzong-Luen Wang, MD, PhD.

Appendix 1.

Glossary of Terms Used in This Summary

Advanced airway	Tracheal tube or supraglottic airway
Compression-only CPR	Chest compressions without active ventilation (eg, mouth-to-mouth ventilation, bag-mask ventilation, or ventilation via an advanced airway)
CPR with ventilation	Chest compressions with PPV; this includes a variety of chest CV ratios and continuous chest compressions with ventilations delivered without pausing chest compressions.
Continuous chest compression CPR	Chest compressions delivered without pausing for ventilation. PPV may (often at 10 breaths per minute) or may not be provided. Maintenance of airway patency may enable passive ventilation.
Dispatch-assisted CPR	A bystander provides CPR under telephone instruction by an EMS dispatcher, most often compression-only CPR. Alternative terminology for these dispatchers includes telecommunicators, ambulance communication officers, emergency medical communicators, and call handlers.

Appendix 2.

GRADE Terminology

Risk of bias	Study limitations in randomised trials include lack of allocation concealment, lack of blinding, incomplete accounting of patients and outcome events, selective outcome reporting bias, and stopping early for benefit. Study limitations in observational studies include failure to apply appropriate eligibility criteria, flawed measurement of exposure and outcome, failure to adequately control confounding, and incomplete follow-up.
Inconsistency	Criteria for inconsistency in results include the following: point estimates vary widely across studies; CIs show minimal or no overlap; statistical test for heterogeneity shows a low *P* value; and the I^2 is large (a measure of variation in point estimates resulting from among-study differences).
Indirectness	Sources of indirectness include differences in population (eg, OHCA instead of in-hospital cardiac arrest, adults instead of children), differences in the intervention (eg, different CV ratios), differences in outcome, and indirect comparison.
Imprecision	Low event rates or small sample sizes will generally result in wide CIs and therefore imprecision.
Publication bias	Several sources of publication bias include tendency not to publish negative studies and influence of industry-sponsored studies. An asymmetrical funnel plot increases suspicion of publication bias.
Good practice statements	Guideline panels often consider it necessary to issue guidance on specific topics that do not lend themselves to a formal review of research evidence. The reason might be that research into the topic is unlikely to be located or would be considered unethical or infeasible. Criteria for issuing a nongraded good practice statement include the following: overwhelming certainty that the benefits of the recommended guidance will outweigh harms and a specific rationale is provided; the statements should be clear and actionable to a specific target population; the guidance is deemed necessary and might be overlooked by some providers if not specifically communicated; and the recommendations should be readily implementable by the specific target audience to which the guidance is directed.

Disclosures

Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Expert Witness	Ownership Interest	Consultant/Advisory Board	Other
Theresa M. Olasveengen	Oslo University Hospital (Norway)	Laerdal Foundation (unrestricted research grant)[*]; South-Eastern Regional Health Authority (unrestricted research grant)[†]	None	None	None	None	None	None
Richard Aickin	Starship Children's Hospital (New Zealand)	None	None	None	None	None	None	None
Dianne L. Atkins	University of Iowa	None	None	None	None	None	None	None
Robert A. Berg	Children's Hospital of Philadelphia	None	None	None	None	None	None	None
Robert M. Bingham	Great Ormond Street Hospital NHS Foundation Trust (United Kingdom)	None	None	None	None	None	None	None
Steven C. Brooks	Queen's University (Canada)	Heart and Stroke Foundation of Canada (research operating grant to study a mobile device application designed to increase bystander resuscitation for OHCA)[†]	None	None	None	None	None	None
Maaret Castrén	Helsinki University Hospital (Finland)	None	None	SMACC Berlin[*]; EMS2017[*]	None	None	None	None
Sung Phil Chung	Yonsei University College of Medicine (Republic of Korea)	None	None	None	None	None	None	None
Julie Considine	Deakin University (Australia)	None	None	None	None	None	None	None
Thomaz Bittencourt Couto	Hospital Israelita Albert Einstein (HIAE), São Paulo, Brazil; department: Centro de Simulação Realística (CSR) AND Unidade de Pronto Atendimento (UPA); Instituto da Criança do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo (ICr-HCFMUSP), São Paulo, Brazil; department: Pronto Socorro	None	None	None	None	None	None	None
Allan R. de Caen	University of Alberta, Stollery Children's Hospital (Canada)	None	None	None	None	None	None	None
Raffo Escalante	Inter-American Heart Foundation (Peru)	None	None	None	None	None	None	None

Raúl J. Gazmuri	Rosalind Franklin University of Medicine and Science	DePaul-Rosalind Franklin University Collaborative Pilot Research Grant Program (basic science research: study mechanisms by which cyclophilin-D modulates transcription of mitochondrial genes)[†]; Department of Defense US Army Medical Research and Material Command (translational research: sustained V1A receptor activation for prolonged haemodynamic support and neurological protection after noncompressible haemorrhage and traumatic brain injury)[†]; Zoll Medical Corp (translational research: AMSA to guide shock delivery in a swine model of ventricular fibrillation and closed chest resuscitation)[†]; James R. & Helen D. Russell Institute for Research & Innovation: Small Research Grants Program (basic science research: prevention of oxidative injury to the neonatal heart)[*]	None	None	None	None	None	None
Anne-Marie Guerguerian	The Hospital for Sick Children (Canada)	None	None	None	None	None	None	None
Tetsuo Hatanaka	Kyoto Prefectural University of Medicine (Japan)	None	None	None	None	None	None	None
Mary Fran Hazinski	Vanderbilt University	None	None	None	None	None	American Heart Association ECC[†]	None
Rudolph W. Koster	Academic Medical Center (the Netherlands)	Physio Control (funding for data management, researchers, equipment)[†]	None	None	None	None	Physio Control[*]	None
Peter J. Kudenchuk	University of Washington Medical Center	None	None	None	None	None	None	None

Eddy Lang	University of Calgary (Canada)	None	None	None	None	None	None	None
Swee Han Lim	Singapore General Hospital (Singapore)	None	None	None	None	None	None	None
Bo Løfgren	Aarhus University Hospital (Denmark)	None	None	None	None	None	None	European Resuscitation Council, International BLS/AED Course Committee[*]
Ian K. Maconochie	St. Mary's Hospital (United Kingdom)	None	None	None	None	None	None	None
Mary E. Mancini	University of Texas at Arlington	None	None	None	None	None	Physio Control[*]	None
Peter A. Meaney	Children's Hospital of Philadelphia	None	None	None	2017, Defense witness, ICU care of graft vs host disease[*]	None	None	None
William H. Montgomery	Straub Clinic and Hospital	None	None	None	None	None	American Heart Association[†]	None
Peter T. Morley	University of Melbourne (Australia)	None	None	None	None	None	None	None
Laurie J. Morrison	St. Michael's Hospital (Canada)	Canadian Institute for Health Research (operating grant for 5 years without salary support)[†]; Heart and Stroke Foundation of Canada (operating grant for 5 years without salary support)[†]	None	None	None	None	None	None
Vinay M. Nadkarni	Children's Hospital of Philadelphia	None	None	None	None	None	None	None
Kevin J. Nation	New Zealand Resuscitation Council (New Zealand)	None	None	None	None	None	None	None
Kee-Chong Ng	KK Hospital (Singapore)	None	None	None	None	None	None	None
Chika Nishiyama	Kyoto University (Japan)	None	None	None	None	None	None	None
Jerry P. Nolan	Royal United Hospital, Bath (United Kingdom)	UK National Institute of Health Research (NIHR research grants for AIRWAYS-2 and PARAMEDIC-2 studies)[*]	None	None	Medicolegal reports relating to resuscitation[†]	None	None	None
Gabrielle Nuthall	Starship Children's Hospital (New Zealand)	None	None	None	None	None	None	None
Gene Yong-Kwang Ong	KK Women's and Children's Hospital (Singapore)	None	None	None	None	None	None	None
Gavin D. Perkins	Warwick Medical School and Heart of England NHS Foundation Trust (United Kingdom)	None	None	None	None	None	None	None
Amelia G. Reis	Inter-American Heart Foundation (Brazil)	None	None	None	None	None	None	None
Giuseppe Ristagno	Italian Resuscitation Council-Scientific Committee (Italy)	None	None	None	None	None	None	None

Tetsuya Sakamoto	Teikyo University (Japan)	None	None	None	None	None	None	None
Michael R. Sayre	University of Washington	None	None	None	None	None	None	Physio-Control Inc. (Funds EMS Medicine Fellowship at University of Washington. I have travel reimbursement from those funds.)*
Stephen M. Schexnayder	University of Arkansas/Arkansas Children's Hospital	None	None	None	None	None	American Heart Association (course development and scientific editing consultant)†	None
Naoki Shimizu	Tokyo Metropolitan Children's Center (Japan)	None	None	None	None	None	None	None
Alfredo F. Sierra	Inter-American Heart Foundation (Mexico)	None	None	None	None	None	None	None
Eunice M. Singletary	University of Virginia	None	None	None	None	None	American Red Cross (chair, First Aid Subcouncil of the Scientific Advisory Council)*	None
Michael A. Smyth	University of Warwick (United Kingdom)	None	None	None	None	None	None	None
David Stanton	Resuscitation Council of Southern Africa (South Africa)	None	None	None	None	None	None	Netcare 911 (head, Clinical Leadership)†
Janice A. Tijssen	London Health Services Center (Canada)	Heart and Stroke Foundation of Canada grant in aid (grant recipient for research)*	None	None	None	None	None	None
Andrew Travers	Emergency Health Services, Nova Scotia (Canada)	None	None	None	None	None	None	None
Christian Vaillancourt	University of Ottawa, Ottawa Hospital Research Institute (Canada)	CIHR (Grant for c-spine rule implementation)†; CIHR and HSFC (CanROC Steering Committee Chair)†	None	None	None	None	None	None
Patrick Van de Voorde	Self-employed	None	None	None	None	None	None	None

Reviewer Disclosures

Reviewer	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
Mioara D. Manole	University of Pittsburgh	None	None	None	None	None	None	None
Arthur B. Sanders	Arizona Health Sciences Center	None	None	None	None	None	None	None
Demetris Yannopoulos	University of Minnesota	None	None	None	None	None	None	None

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