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DIAGNOSIS OF OUT-OF-HOSPITAL CARDIAC ARREST BY EMERGENCY MEDICAL DISPATCH: A DIAGNOSTIC SYSTEMATIC REVIEW

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ABSTRACT

Introduction Cardiac arrest is a time-sensitive condition requiring urgent intervention. Prompt and accurate recognition of cardiac arrest by emergency medical dispatchers at the time of the emergency call is a critical early step in cardiac arrest management allowing for initiation of dispatcher-assisted bystander CPR and appropriate and timely emergency response. The overall accuracy of dispatchers in recognizing cardiac arrest is not known. It is also not known if there are specific call characteristics that impact the ability to recognize cardiac arrest.

Methods We performed a systematic review to examine dispatcher recognition of cardiac arrest as well as to identify call characteristics that may affect their ability to recognize cardiac arrest at the time of emergency call. We searched electronic databases for terms related to "emergency medical dispatcher", "cardiac arrest', and "diagnosis," among others, with a focus on studies that allowed for calculating diagnostic test characteristics (e.g. sensitivity and specificity). The review was consistent with Grading of Recommendations, Assessment, Development and Evaluation (GRADE) method for evidence evaluation.

Results We screened 2520 article titles, resulting in 47 studies included in this review. There was significant heterogeneity between studies with a high risk of bias in 18 of the 47 which precluded performing meta-analyses. The reported sensitivities for cardiac arrest recognition ranged from 0.46 to 0.98 whereas specificities ranged from 0.32 to 1.00. There were no obvious differences in diagnostic accuracy between different dispatching criteria/algorithms or with the level of education of dispatchers.

Conclusion The sensitivity and specificity of cardiac arrest recognition at the time of emergency call varied across dispatch centres and did not appear to differ by dispatch algorithm/criteria used or education of the dispatcher, although comparisons were hampered by heterogeneity across studies. Future efforts should focus on ways to improve sensitivity of cardiac arrest recognition to optimize patient care and ensure appropriate and timely resource utilization.

Introduction

The provision of bystander CPR is associated with a three-fold increase in survival from out-of-hospital cardiac arrest (OHCA).[1] Systems with high levels of citizen CPR training and associated high levels of bystander CPR delivery report excellent cardiac arrest outcomes.[2] However, even in situations where bystanders lack training, dispatchers can effectively coach CPR delivery over the telephone (dispatcher-assisted cardiopulmonary resuscitation- DACPR). Of note, a variety of terms have been used to describe this activity, along with the call-taker(s) at the emergency dispatch center who receive calls, interact with the caller, determine the nature of the emergency, provide phone instructions if required and triage the needed emergency service personnel to the scene. These terms include, call-receiver, dispatcher, and telecommunicator, among others. Given that the most common term currently used in the literature has been dispatcher, this descriptor was chosen to designate this individual in this review. Irrespective of the actual nomenclature used, the delivery of DACPR has been shown to increase the number of bystanders who perform CPR prior to EMS arrival.[3] Further, recognition of cardiac arrest allows for prioritization of cardiac arrest calls to enable faster response times and the allocation of appropriate resources.

Underpinning this process is the need for emergency dispatchers to make a correct presumptive diagnosis of cardiac arrest. This challenging diagnosis is based on verbal descriptions and other auditory cues provided by the caller, coupled with the dispatcher's suspicions based on their training and experience. A number of algorithms have been developed to support dispatchers in determining whether or not the patient has had a cardiac arrest. These algorithms may be supplemented by other factors, such as the caller's emotional state or overhearing sounds at the scene such as agonal breathing, in making the diagnosis of cardiac arrest. Despite these efforts and the potential for CPR to be initiated at the scene as a result of dispatcher prompting, bystander CPR rates remain low in many systems.[4,5] This may reflect a number of factors such as bystander's inability or unwillingness to perform CPR, but just as importantly, the failure for the emergency dispatcher to recognize cardiac arrest.[6]

The purpose of this systematic review was twofold: first, to evaluate the diagnostic accuracy of dispatch centers to diagnose cardiac arrest over the phone, and second, to examine whether specific characteristics of the call process impact on the ability of dispatchers to diagnose cardiac arrest. In examining the call process, we evaluated words, language, or idioms used by the caller, perceptions of the dispatcher, as well as their training and experience, emotional state of the caller, caller characteristics, background noises, and availability of call screening tools (dispatch algorithms).

Methods

We performed a diagnostic systematic review to collect and examine evidence related to dispatcher recognition of cardiac arrest. This systematic review was commissioned by the International Liaison Committee on Resuscitation (ILCOR). This review was registered with PROSPERO (CRD 42019140265) and is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRIMSA) guidelines.

Search strategy and selection criteria

We searched bibliographic databases (Embase, Ovid Medline, the Cochrane Central register of Controlled Trials (CENTRAL), the Cochrane Database of Systematic Reviews, CINAHL, and ERIC) from database inception to April 24, 2019. Our search strategy, adapted for each database, used a comprehensive combination of subject headings and keywords for the three concepts of emergency medical dispatch, cardiac arrest, and diagnosis, combined using the Boolean operator "AND". Our search was developed utilizing the expertise of a data information specialist from St. Michael's Hospital, Toronto, Canada. We searched clinical trial registries (www.clinicaltrials.gov, www.isrctn.com, and http://www.who.int/ictrp/en/) to identify ongoing clinical research. We also hand-searched reference lists of key articles to ensure key articles had not been overlooked. No language limits were applied. Our search was repeated on November 28, 2019 to identify any additional relevant studies that were published during our review process. A detailed Medline search strategy can be found in the appendix.

Our population of interest was both adult and pediatric patients with presumed cardiac arrest. We were interested in determining the overall diagnostic ability of dispatch centers as a whole and different dispatch algorithms and/or criteria. Where possible, we also identified the previously described characteristics of the call process that might have impacted the ability of dispatchers to correctly diagnose cardiac arrest during the emergency call. The definition of cardiac arrest diagnosis varied across studies. In many studies, cardiac arrest was specifically identified by the dispatcher or identified through the cardiac arrest dispatch algorithm with specific questioning (e.g. “unconscious?” and “abnormal breathing?”). Other studies did not specifically mention how cardiac arrests were identified and dispatch offering of DACPR was used as a surrogate of cardiac arrest recognition.

We included randomized and non-randomized clinical trial designs as well as observational research studies (cohort studies, case-control studies, and cross-sectional studies). We excluded case studies, case series, conference abstracts, simulation studies, and protocols specifically developed for clinical trials, as well as studies for which we were unable to abstract data required to calculate our outcomes of interest.

Our pre-defined outcomes of interest in order of importance were; sensitivity (critical), false negative rate (critical), specificity (important), false positive rate (important), positive predictive value (important), negative predictive value (important), positive likelihood ratio (important), negative likelihood ratio (important), and diagnostic odds ratio (important).

Two members of the research team (ID and GG) independently performed article screening at the title, abstract, and full manuscript level. Discrepancies between reviewers was first resolved through consensus, followed by a third reviewer if required. Kappa statistics were calculated for the abstract and full manuscript review. Data abstraction occurred utilizing double data abstraction. Two members of the team (ID and GG) independently abstracted data utilizing a pre-defined, mutually agreed upon template. Again, discrepancies were resolved through discussion to reach consensus, followed by use of a third reviewer as required.

Risk of bias assessments were performed independently by two researchers (ID, GG, KC) using the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool[7,8], and discrepancies were resolved through consensus. The overall quality of evidence was reported utilizing the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) process.[9]

Where feasible, we calculated outcomes of interest for each individual study included from the full text review. We planned to perform meta-analyses where this was not precluded by low quality of evidence, or clinical or statistical heterogeneity. On initial data review, we concluded that a meta-analysis was not appropriate, so our findings are described narratively. We performed subgroup analyses based on specific dispatch algorithms or criteria utilized as well as whether or not the emergency dispatchers had previous medical education training.

Results

The search was performed on November 28, 2019 and spanned studies published from database inception to the date of search. We identified a total of 2520 studies after removing duplicate results. Hand searching key articles and expert consensus did not identify any additional articles for inclusion. We identified a total of 233 abstracts for review and 94 full manuscripts leading to 47 studies included in our analysis, having a kappa of 0.60 and 0.85 at the abstract and full manuscript review level respectively. (Figure 1)

The included studies were comprised of 873,538 adult patients, 84,534 (9.7%) of whom had OHCA, and 53,211 pediatric patients, 122 (0.2%) of whom had OHCA. The characteristics of each study are reported in table 1. Studies were conducted in a number of countries with the most common being the United States (n=10), followed by Finland, (n=4), United Kingdom (n=3), France (n=3), Denmark (n=3), Japan (n=3), Taiwan (n=3), Sweden (n=2), Norway (n=2), Canada (n=2), Switzerland (n=2), and single studies in Australia, and the Netherlands, Singapore, Korea, Czech Republic, Iran, and Belgium. One study examined dispatch centers in the United States and Norway and another study looked at Denmark and Sweden. All studies were published between 1994 and 2019. Emergency dispatch centres in the included studies utilized a variety of standardized proprietary algorithms such as Advanced Medical Priority Dispatch Software (AMPDS) or the Norwegian Index to Emergency Medical Assistance to identify cardiac arrests. Other dispatch centres relied on Criteria-based Dispatch or ad hoc dispatcher judgement. There was a varying degree of training and experience within EMD personnel reported across the studies. A single study by Deakin et al. (2017) specifically examined cardiac arrest recognition in pediatric patients. All of the other studies included a general population of cardiac arrest patients (adult or mixed adult/pediatric patients).

Risk of bias for individual studies

Across the 47 included studies, we assessed overall risk of bias (using the QUADAS-2 tool)[8] as low in 22 studies, high in 18 studies, and unclear in 7 studies (Table 2). Due to the overall high risk of bias in many of these studies and the clinical heterogeneity among them, a meta-analysis was not performed. The denominator of included patients was significantly different across included studies and one of the main contributors to heterogeneity between studies. This was most apparent in comparing studies that included unconscious patients to studies including all emergency calls.

Sensitivity of Cardiac Arrest Diagnosis (critical)

For the critical outcome of sensitivity of cardiac arrest diagnosis in a general population of cardiac arrest patients we identified very low certainty evidence (downgraded for serious risk of bias, inconsistency and imprecision) from 46 observational studies examining OHCA in general cardiac arrest patients (n=84,534).[3,6,10-53] The median sensitivity for recognizing OHCA was 0.79 (interquartile range (IQR) 0.69, 0.83) and ranged from a low of 0.46 (95% CI 0.45, 0.46) to a high of 0.98 (95% CI 0.96, 0.98)(Figure 2). In a single observational study (low certainty of evidence) of OHCA in a pediatric population, of whom 122 had OHCA, the sensitivity was 0.71 (95% CI 0.63, 0.79).[54]

False Negative Rates of Cardiac Arrest Diagnosis (Critical)

For the critical outcome of false negative cardiac arrest diagnoses (e.g. cardiac arrest was present when it was not diagnosed by the emergency dispatcher) we identified very low certainty evidence (downgraded for serious risk of bias, inconsistency and imprecision) among the aforementioned 46 studies of OHCA in the general population (adult only, or mixed adult/pediatric patients). The median reported false negative rate for cardiac arrest recognition was 0.21 (IQR 0.17, 0.32) and ranged from 0.03 (95% CI 0.02, 0.03) to 0.54 (95% CI 0.54, 0.55).[3,6,10-53] The single pediatric study had a false negative rate of 0.29 (95% CI 0.21, 0.37)[54]

Specificity of Cardiac Arrest Diagnosis (Important)

For the important outcome of specificity of cardiac arrest diagnoses we identified low certainty evidence (downgraded for serious risk of bias and inconsistency) from 12 observational studies involving 789,004 OHCA patients. The median specificity was 0.99 (IQR 0.93, 1.00) and ranged from 0.32 (95% CI 0.29, 0.36) to 1.00 (95% CI 1.00, 1.00).[10,17,20-22,39-41,46,48,52,53] The specificity for pediatric OHCA (n=53,089) was 0.96 (95% CI 0.96, 0.97).[54] (Figure 3)

False Positive Rates of Cardiac Arrest Diagnosis (Important)

For the important outcome of false positive rates, we identified low certainty evidence (downgraded for serious risk of bias and inconsistency) from 12 observational studies (789,004 OHCA patients) showing a median false positive rate for cardiac arrest recognition of 0.01 (IQR 0.01, 0.07) with a range from 0.002 (95% CI 0.001, 0.002) to 0.68 (95% CI 0.64, 0.71).[10,17,20-22,39-41,46,48,52,53] The false positive rate for identification of cardiac arrest in pediatric patients was reported as 0.04 (95% CI 0.04, 0.04).[54]

Positive Predictive Value of Cardiac Arrest Diagnosis (Important)

For the important outcome of positive predictive value, we identified low certainty evidence (downgraded for serious risk of bias and inconsistency) from 12 observational studies (789,004 OHCA patients). These studies showed a median positive predictive value for cardiac arrest recognition of 0.76 (IQR 0.50, 0.85), ranging from 0.09 (95% CI 0.08, 0.10) to 0.95 (95% CI 0.90, 0.98).[10,17,20-22,39-41,46,48,52,53] The positive predictive value in pediatric OHCA patients was low at 0.04 (95% CI 0.03, 0.05).[54]

Negative Predictive Value for Cardiac Arrest Diagnosis (Important)

For the important outcome of negative predictive value, we identified low certainty evidence (downgraded for serious risk of bias and inconsistency) from 12 observational studies (789,004 OHCA patients). These showed a median negative predictive of 1.00 (IQR 0.92, 1.00), ranging from 0.31 (95% CI 0.28, 0.34) to 1.00 (95% CI 1.00, 1.00).[10,17,20-22,39-41,46,48,52,53] The negative predictive value for cardiac arrest diagnosis in pediatric OHCA was 1.00 (95% CI 1.00, 1.00).[54]

Positive Likelihood Ratio for Cardiac Arrest Diagnosis (Important)

For the important outcome of positive likelihood ratio, we identified low quality evidence (downgraded for serious risk of bias and inconsistency) from 12 observational studies for OHCA showing a median value of 54.72 (IQR 11.28, 152.22) and ranging from 0.97 (95% CI 0.92, 1.04) to 591.77 (95% CI 474.19, 738.51).[10,17,20-22,39-41,46,48,52,53] For pediatric OHCA the positive likelihood ratio was 19.27 (95% CI 17.08, 21.74).[54]

Negative Likelihood Ratio for Cardiac Arrest Diagnosis (Important)

For the important outcome of negative likelihood ratio, we identified low certainty evidence (downgraded for serious risk of bias and inconsistency) from 12 observational studies (789,004 OHCA patients).[10,17,20-22,39-41,46,48,52,53] The median negative likelihood ratio for OHCA in general OHCA patients was 0.22 (IQR 0.19, 0.24) and ranged from 0.04 (95% CI 0.03, 0.07) to 1.06 (95% CI 0.93, 1.20). The negative likelihood ratio for pediatric OHCA recognition was 0.30 (95% CI 0.23, 0.39).[54]

Dispatch algorithms and criteria

We performed a secondary analysis grouping studies according to the type of dispatch algorithm/criteria that were used as well as whether the dispatcher had any prior education/experience as a healthcare provider. Again, due to the potential for heterogeneity between studies we did not pool the study results. We found no apparent differences in cardiac arrest recognition accuracy based on the type of dispatching algorithm utilized or the prior education and background of the emergency dispatchers. However, there was considerable variability noted between studies within these subgroup characteristics, making it difficult to draw definitive conclusions regarding their potential impact on OHCA recognition (Figure 4 and 5). A single study directly compared different dispatching criteria (MPD vs criteria-based dispatch) and found no difference in rates of dispatcher recognition, 82% vs. 77% (P value = 0.42) respectively.[27]

Training

We identified two studies[28,55] that found that an educational intervention targeted at dispatchers improved cardiac arrest recognition at the time of emergency call. Both studies found significant improvements in dispatcher recognition of cardiac arrest with targeted educational interventions. Hardeland et al. (2017) performed an interventional study utilizing targeted education, simulation, and feedback for emergency medical communication officers. Post-intervention they found a significant improvement in the recognition of cardiac arrest (95% vs. 89%, P = 0.02), a reduction in the misinterpretation of agonal breathing (10% vs. 25%, P <0.001) and faster time to initiation of chest compression instructions, 2.3 minutes vs. 2.6 minutes (P = 0.04).[28] Similarly, Meischke et al. (2017) performed a randomized controlled trial of 157 emergency medical dispatchers randomized to simulation training or no additional training. They found that dispatchers randomized to simulation training were able to recognize the need for DACPR more often than those who did not complete the training for more challenging cardiac arrest calls (68% vs 53%, P=0.018).[55]

Discussion

In this systematic review spanning 47 studies and 926,749 patients, we observed clinically important heterogeneity across studies in relation to dispatcher algorithms, experience, and education. The diagnostic accuracy of the dispatch systems evaluated varied markedly across studies. The degree of heterogeneity along with the variability in study results did not allow for pooling of data in meta-analyses.

For our pre-determined critical outcome of sensitivity of dispatcher recognition of cardiac arrest there were significant differences in the results of included studies, suggesting wide variability in dispatchers' abilities to recognize patients who are in cardiac arrest at the time of emergency call across call centers. We found no obvious differences in sensitivity or specificity among call centres using different dispatch algorithms/criteria; nor based on the reported previous experience or education of the dispatcher as prior healthcare providers.

Our findings have important practical implications. As with any diagnostic test, there is a need to consider both the sensitivity and specificity of the test itself, as well as its overall utility (predictive value) when applied to the greater population of in-coming emergency calls pertaining to patients with and without OHCA. Recognition of cardiac arrest by a dispatcher facilitates the delivery of bystander CPR which is a critical component in optimizing outcomes from OHCA. Over-diagnosis, however, exposes individuals not in cardiac arrest to potential harms from chest compressions such as rib fractures, as well as more potentially serious injuries, and results in the inappropriate deployment of specialist EMS resources. At a population level, the small risks associated with over-diagnosis are likely outweighed by the life-threatening implications of under-diagnosis. A further consideration is the time taken to make a diagnosis of cardiac arrest. Delays in the initiation of bystander CPR are associated with a reduced likelihood of survival. These factors mean that emergency systems are likely to prefer a test that can be performed rapidly and which has high sensitivity, over a test that is highly specific.

Recognition of OHCA at an emergency call center is typically based on verbal responses from a caller to set questions from a dispatcher related to level of consciousness and the presence of normal breathing. Recent research highlights the potential important contributions of linguistics to the rapid identification of cardiac arrest. Lewis et al. (2013) found that the language used by the caller to describe the presence of agonal breathing was associated with dispatcher recognition of cardiac arrest. The identification of agonal breathing was consistently reported as one of the biggest barriers to cardiac arrest recognition.[23,24]

Developing technology may also enable live-streaming of the scene to the dispatcher to aid in diagnosis. We identified a single study that compared cardiac arrest recognition utilizing a machine learning algorithm to dispatcher recognition. The machine algorithm was able to accurately recognize more patients who were in cardiac arrest compared to the emergency dispatcher (sensitivity 84.1% vs. 72.5%) without a large decrease in specificity (97.3% vs.

98.8%).[12] The strength of this technology lies in the ability to rapidly assimilate information from a number of sources to support the dispatcher's diagnosis of cardiac arrest and could serve as an aid to diagnosing OHCA. As technology develops it will invite evaluation and comparison with the human-based approaches discussed here, but at present fall outside the scope of this review.

Local emergency dispatch centres need systems in place to accurately monitor and track their performance in cardiac arrest recognition at the time of emergency call. The wide range of reported sensitivities between call centers indicates the need and potential for improvement among poorly performing centers. Dispatcher training may require particular attention. We identified two studies[28,55] that found that an educational intervention targeted at dispatchers improved cardiac arrest recognition at the time of emergency call.

Our review has a number of limitations. First, the manner in which data were reported in the index studies precluded analysis of individual factors that were associated with improved or decreased diagnostic accuracy. While studies were identified that examined barriers to dispatcher recognition it was not possible to abstract data that could be used to calculate diagnostic test characteristics. Second, we were unable to perform a meta-analysis due to significant risk of bias and clinical heterogeneity across studies. Third, we were unable to extract data to calculate specificity from most papers, as the number of true negatives was not reported. In studies where specificity was reported, the number of true negatives was not defined consistently. In some, true negatives were defined as all emergency calls, whereas in other studies true negatives only included patients identified as unresponsive but not in cardiac arrest. In order for the patient population under study to be more representative of the true ability to rule out cardiac arrest at the time of emergency call, ideally the reported denominator should only include patients who had the possibility of being in cardiac arrest at the time of the call (e.g. unconscious patients). Among studies that reported such a denominator we found that the overall specificity was significantly lower than when this was not the case, suggesting that dispatchers had a harder time determining patients that were not in cardiac arrest in this population. Due to the availability of extremely limited pediatric data, any conclusions drawn from this review would be speculative.

Conclusion

Overall we found that the sensitivity and specificity of cardiac arrest recognition at the time of emergency call varied across dispatch centres and did not appear to differ by dispatch algorithm/criteria used or education of the dispatcher, although comparisons were hampered by heterogeneity across studies. Future efforts should focus on ways to improve sensitivity of cardiac arrest recognition to optimize patient care and ensure appropriate and timely resource utilization.

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Conflict of Interest

Some of the authors (T.Olasveengen) and Task Force collaborators (C Vaillancourt, M Castren, Judith Finn) have published manuscripts related to dispatcher recognition of cardiac arrest which are included in this review. T.O. has received research funding from Zoll Foundation and Laerdal Foundation. No other authors report any financial conflicts of interests and none of the authors have academic conflicts related to ongoing or planned trials.

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Table 1

Table 1: Characteristics of included studies

STUDY	AUTHOR	STUDY YEAR	LOCATION	YEAR(S)	STUDY DESIGN	INCLUSION	DISPATCH ALGORITHM	PATIENT NO.
1	Berdowski, J.	2009	Netherlands	2004	Prospective Cohort	High priority emergeny calls by lay responders	Standard Algorithm: "Conscious" and "Breathing"	9579
2	Besnier, E.	2015	France	2009-2012	Before-and-After Study	All non-traumatic OHCA with untrained witness	No Standard Algorithm: "Conscious" and "Breathing"	395
3	Blomberg, S.	2019	Denmark	2014	Retrospective Cohort	All emergency calls	Criteria-Based Dispatch	107,689
4	Bohm, K.	2007	Sweden	2004	Retrospective Cohort	Witnessed OHCA	Swedish Medical Index (CBD) - based on Norwegian Index to Emergency Medical Assistance	76
5	Bohm, K.	2009	Sweden	2004 & 2006	Retrospective Cohort	Witnessed OHCA, presumed cardiac, ≥ 9 years old	Swedish Medical Index (CBD) - based on Norwegian Index to Emergency Medical Assistance	152
6	Cairns, K.	2008	Northern Ireland	2004	Retrospective Cohort	All emergency events and OHCA	AMPDS v11.1	181
7	Castren, M.	2001	Finland	1996	Retrospective Cohort	Non-traumatic cardiac arrest, witnessed or ongoing bystander CPR	Criteria-Based, Computer-Aided Dispatch	328
8	Chien, C.	2019	Taiwan	2015-2016	Cross-sectional	All adult (≥ 18 years) non-traumatic OHCA	CBD: "is the patient conscious?", "Is patient breathing normally?"	367
9	Clark, J.	1994	United States	1992	Retrospective Cohort	All OHCA and initial complaint resembling cardiac arrest	CBD: "Conscious" and "Breathing Normally"	358
10	Dami, F.	2010	Switzerland	2008-2009	Prospective Cohort	All non-traumatic OHCA	EMD Judgement	294
11	Dami, F.	2015	Switzerland	2011-2013	Prospective Cohort	All OHCA	EMD Judgement	1256
12	Deakin, C.	2017	United Kingdom	2015-2016	Retrospective Cohort	All emergency calls	NHS Pathway	469,400
13	Deakin, C.	2017	United Kingdom	2015-2016	Retrospective Cohort	All emergency calls	NHS Pathway	53,211
14	Derkeene, C.	2019	France	2012, 2015, 2018	Repeat Cross-Sectional	All OHCA	detect unconsiousness then "Hands on Belly" algorithm to detect cardiac arrest	321
15	Flynn, J.	2006	Australia	2003	Retrospective Cohort	All emergency calls	MPDS	52,895
16	Fukushima, H.	2015	Japan	2011-2012	Prospective Cohort	Unresponsive adult (≥18 years) transported patients	CBD: "Conscious" and "Breathing Normally"	140
17	Fukushima, H.	2015	Japan	2007-2009	Retrospective Cohort	Adult (≥18 years) OHCA transported to hospital	CBD: "Conscious" and "Breathing Normally"	283
18	Fukushima, H.	2017	United States	2010-2014	Retrospective Cohort	All non-traumatic OHCA	Local Protocols (80%); MPDS (20%)	2411
19	Fukushima, H.	2016	United States	2012-2013	Retrospective Cohort	All non-traumatic OHCA	Local Protocols (80%); MPDS (20%)	1850
20	Garza, A.	2003	United States	2000	Retrospective Cohort	Calls with field diagnosis or code for cardiac arrest	AMPDS	506
21	Green, J.	2019	United Kingdom	2016-2017	Retrospective Cohort	All emergency calls	National Health Services Pathway (NHSP)	71,363
22	Hardeland, C.	2014	United States / Norway	:007 & 2010-201	Retrospective Cohort	All cardiac arrests	MPDS and Norwegian Medical Index	240
23	Hardeland, C.	2017	Norway	2013-2014	Prospective Interventional St	All ambulance-confirmed OHCA	Norwegeian Index for Emergency Medical Assistance	561
24	Hardeland, C.	2016	Norway	2013-2014	Mixed Methods Study	All adult OHCA	Norwegeian Index for Emergency Medical Assistance	579

Table 1: Cont'd

25	Hauff, S.	2003		2000-2002	Retrospective Cohort	All adult (≥ 18 years) OHCA prior to EMS arrival, not in medical or nursing facility	CBD	404
26	Ho, A.	2016	Singapore	2012-2015	Retrospective Cohort	All OHCA	CBD: "Conscious" and "Breathing Normally"	1157
27	Huang, C.	2017	Taiwan	2014-2016	Before-and-After Study	All adult (≥ 18 year) with non-traumatic OHCA	CBD: "Conscious" and "Breathing Normally"	130
28	Kuisma, M.	2005	Finland	1997-2002	Retrospective Cohort	OHCA bystander witnessed, VF initial rhythm, presumed cardiac origin	Medical Priority Dispatching Algorithm	373
29	Lee, S.	2018	Korea	2014	Retrospective Cohort	All EMS treated adult (≥ 18 years) OHCA presumed cardiac etiology	CBD: "Altered Mental Status" and "Abnormal breathing"	44,185
30	Lewis, M.	2013	United States	2011	Retrospective Cohort	All adult (≥ 17 years) OHCA prior to EMS arrival	CBD: "Conscious" and "Breathing Normally"	476
31	Linderoth, G.	2015	Denmark	2013-2014	Mixed Methods Study	All OHCA captured by CCTV	Danish Index for Emergency Care	21
32	Ma, M.	2007	Taiwan	2004	Retrospective Cohort	All adult (≥ 18 years) non-traumatic OHCA	Modified Priority Dispatch System Algorithm	199
33	Moller, T.	2016	Denmark / Sweden	2013	Retrospective Cohort	All non-EMS witnessed cardiac arrest	Danish Index for Emergency Care	930
34	Nuno, T.	2017	United States	2010-2013	Retrospective Cohort	All OHCA	CBD: "Conscious" and "Breathing Normally"	3398
35	Nurmi, J.	2006	Finland	1996	Prospective Cohort	Urgent ambulance calls	CBD: "What Happened", "Conscious", "Breathing Normally"	33,650
36	Orpet, R.	2015	United States	2013	Retrospective Cohort	Unconscious patients	CBD: "Conscious" and "Breathing Normally"	679
37	Plodr, M.	2016	Czech Republic	2015	Retrospective Cohort	All emergency calls	CBD: "Conscious" and "Breathing Normally"	341
38	Roppolo, L.	2009	United States		Before-and-After Study	All OHCA	CBD: "Conscious","Breathing" and "Conscious","Breathing Normally"	962
39	Saberian, P.	2019	Iran	2018	Retrospective Cohort	Suspected OHCA	CBD: "is there any response", "does the patient moan?", followed by breathing assessment (hands on stomach) for 10 seconds	4732
40	Shah, M.	2018	United States	2014-2015	Retrospective Cohort	All adult (≥ 18 years) OHCA	Not Reported	2354
41	Stipulante, S.	2014	Belgium	2008-2011	Before-and-After Study	All OHCA	Not Reported	1569
42	Syvaoja, S.	2018	Finland	1997-2013	Retrospective Cohort	All adult (≥ 18 years) OHCA, bystander witnessed, cardiac origin	Criteria Based Dispatch	2054
43	Tanaka, Y.	2014	Japan	2009-2011	Prospective Cohort	All emergency calls	CBD	108,177
44	Travers, A.	2014	France	2012	Prospective Cohort	All OHCA ≥ 15 years with use of an AED	CBD	82
45	Vaillancourt, C.	2015	Canada	2008-2009	Prospective Cohort	Unconscious patients	Dispatch Priority Card Index (Ministry of Health Ontario)	2,260
46	Vaillancourt, C.	2007	Canada	2003-2004	Before-and-After Study	All OHCA of presumed cardiac etiology	Dispatch Priority Card Index (Ministry of Health Ontario)	529
47	Viereck, S.	2017	Denmark	2013	Retrospective Cohort	All OHCA	Danish Index for Emergency Care	779

OHCA = out-of-hospital cardiac arrest; EMS = emergency medical services; CBD = Criteria-based dispatch; CPR = cardiopulmonary resuscitation; AED = automated external defibrillation; MPDS = medical priority dispatch system; VF = ventricular fibrillation; CCTV = closed circuit television

Table 2

Table 2: Risk of Bias Assessment of included studies

STUDY	AUTHOR	YEAR	Patient Selection Risk of Bias (Low, High, Unclear)	Index Test Risk of Bias (Low, High, Unclear)	Reference Standard Risk of Bias (Low, High, Unclear)	Flow of Patients Risk of Bias (Low, High, Unclear)	Are there concerns that the included patients and setting do not match the review question?	Are there concerns that the index test, its conduct, or its interpretation differ from the review question?	Are there concerns that the target condition as defined by the reference standard does not match the question?	Other Conerns	**Overall**
1	Berdowski, J	2009	High	Low	Low	Low	N	Y*	N	N	High
2	Besnier, E	2015	Unclear	Low	Low	Low	Y*	N	N	N	Unclear
3	Blomberg, S	2019	Unclear	Low	Low	Low	N	N	N	N	Low
4	Bohm, K	2007	High	Low	Low	Low	N	N	N	N	Unclear
5	Bohm, K	2009	High	Low	Low	Low	N	N	N	N	High
6	Cairns, K	2008	Unclear	Low	Low	Low	N	N	N	N	Low
7	Castren, M	2001	Low	Low	Low	Low	N	N	N	N	Low
8	Chien, C.	2019	Low	Low	Low	Low	N	N	N	N	Low
9	Clark, J	1994	Low	Low	Low	Low	Y*	N	N	N	High
10	Dami, F	2010	Low	Low	Low	Low	U	Y*	N	N	High
11	Dami, F	2015	Low	Low	Low	High	N	N	N	N	High
12	Deakin, C	2017	Low	Low	Low	Low	N	N	N	N	Low
13	Deakin, C	2017	Low	Low	Low	Low	Y*	N	N	N	Low
14	Derkeene, C.	2019	High	Low	Low	Low	Y	N	N	N	High
15	Flynn, J	2006	Low	Low	Low	Low	Y*	N	N	N	Unclear
16	Fukushima, H	2015	High	Low	Low	High	Y*	N	N	N	High
17	Fukushima, H	2015	High	Low	Low	High	Y*	N	N	N	High
18	Fukushima, H	2017	Unclear	Low	Low	Low	Y*	N	N	N	Unclear
19	Fukushima, H	2016	Low	Low	Low	High	N	N	N	N	High
20	Garza, A	2003	Low	Low	Low	Low	N	N	N	N	Low
21	Green, J	2019	Low	Low	Unclear	Low	Y*	N	Y*	N	Unclear
22	Hardeland, C	2014	Low	Low	Low	Low	N	N	N	N	Low
23	Hardeland, C	2017	Low	Low	Low	Low	N	N	N	N	Low
24	Hardeland, C	2016	Low	Low	Low	Low	N	N	N	N	Low
25	Hauff, S	2003	High	Low	Low	Low	N	Y*	N	N	Unclear
26	Ho, A	2016	Low	Low	Low	High	N	N	N	N	High
27	Huang, C	2017	Low	Low	Low	Low	N	N	N	N	Low
28	Kuisma, M	2005	High	Low	Low	Low	N	N	N	N	High
29	Lee, S	2018	Low	Low	Low	Low	N	N	N	N	Low
30	Lewis, M	2015	High	Low	Low	Low	N	N	N	N	High
31	Linderoth, G	2015	High	Low	Low	Low	Y*	N	N	N	High
32	Ma, M	2007	Low	Low	Low	Low	N	N	N	N	Low
33	Moller, T	2016	Low	Low	Low	Low	N	N	N	N	Low
34	Nuno, T	2017	Low	Low	Low	Low	N	N	N	N	Low
35	Nurmi, J	2006	Low	Low	Low	Low	Y*	N	N	N	Unclear
36	Orpet, R	2015	Low	Low	Low	Low	N	N	N	N	Low
37	Plodr, M	2016	Low	Low	Low	Low	N	N	N	N	Low
38	Roppolo, L	2009	Low	Low	Low	Low	N	N	N	N	Low
39	Saberian, P.	2019	Low	Low	Low	Low	N	N	N	N	Low
40	Shah, M	2018	Low	Low	Low	High	N	N	N	N	High
41	Stipulante, S	2014	Low	Low	Low	Low	N	N	N	N	Low
42	Syvaoja, S	2018	Low	Low	Low	Low	N	N	N	N	Low
43	Tanaka, Y	2014	Low	Low	Low	Low	N	Y*	N	N	High
44	Travers, A	2014	High	Low	Low	High	N	N	N	N	High
45	Vaillancourt, C	2015	Low	Low	Low	Low	Y*	N	N	N	Low
46	Vaillancourt, C	2007	Low	Low	Low	High	N	N	N	N	High
47	Viereck, S	2017	Low	Low	Low	High	N	N	N	N	High

Figure 1

Figure 1: Study Inclusion Diagram

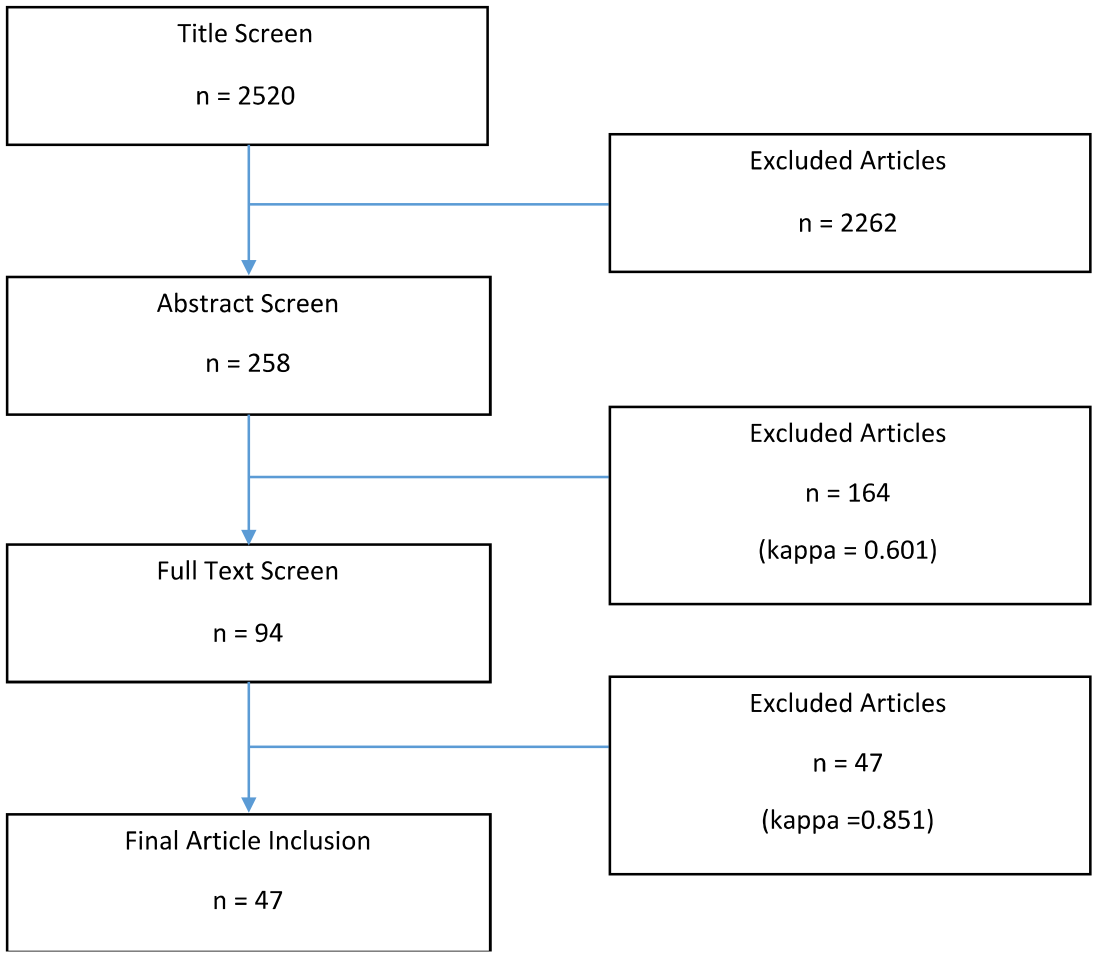


Figure 2

Figure 2: Forest plot of sensitivity of cardiac arrest recognition

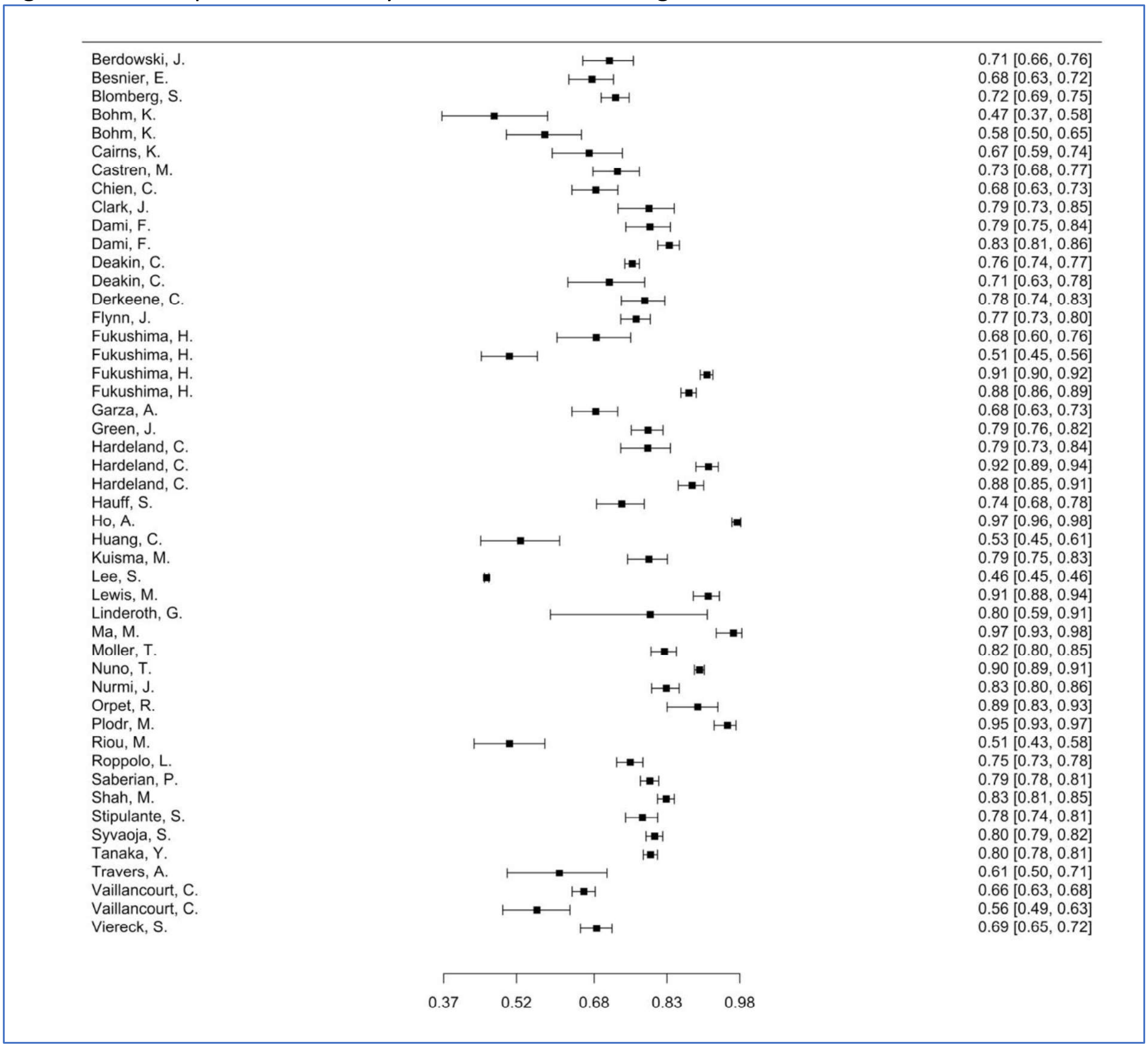


Figure 3

Figure 3: Specificity of cardiac arrest recognition

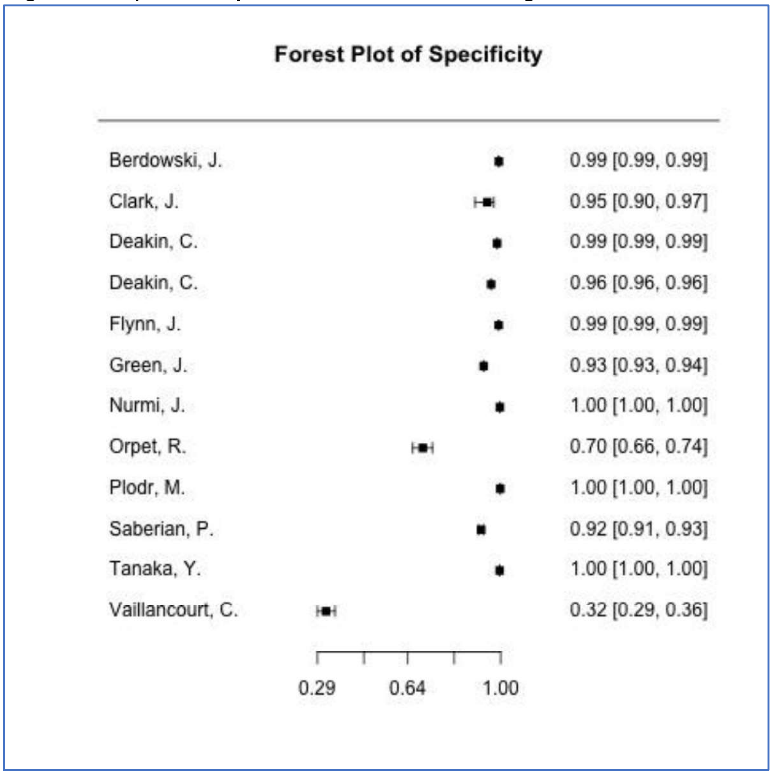
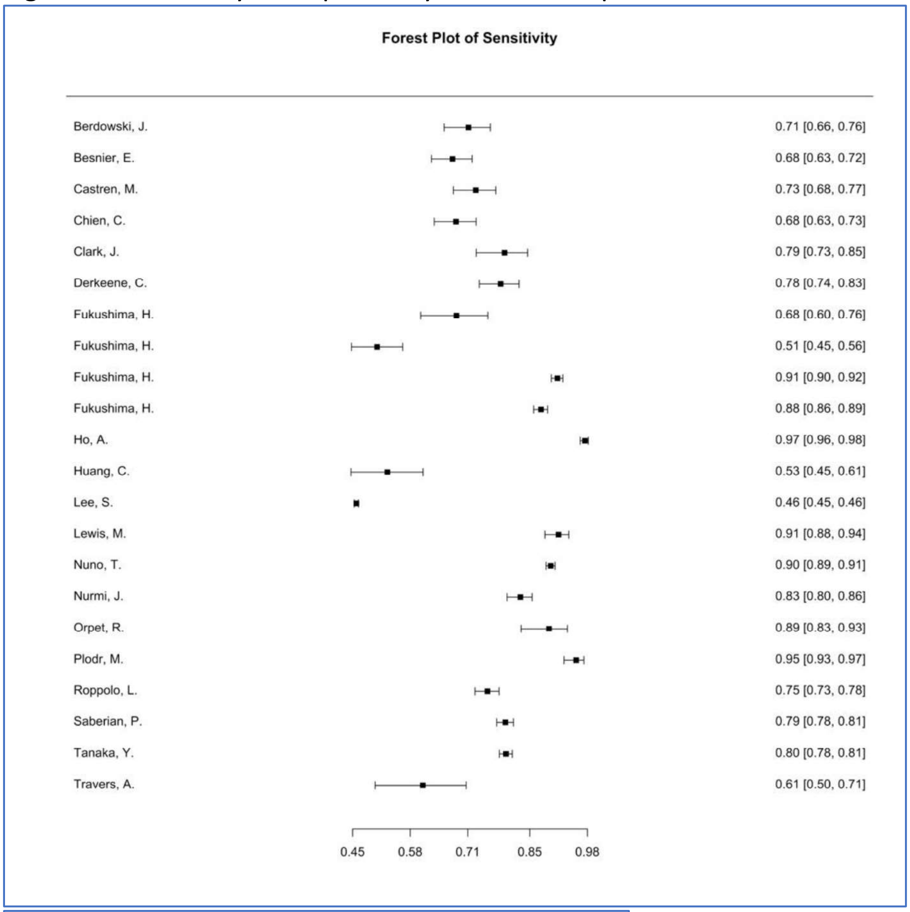
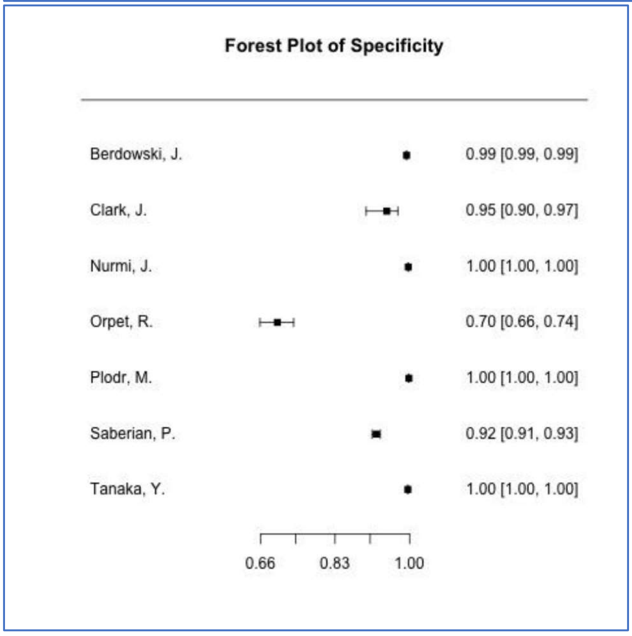


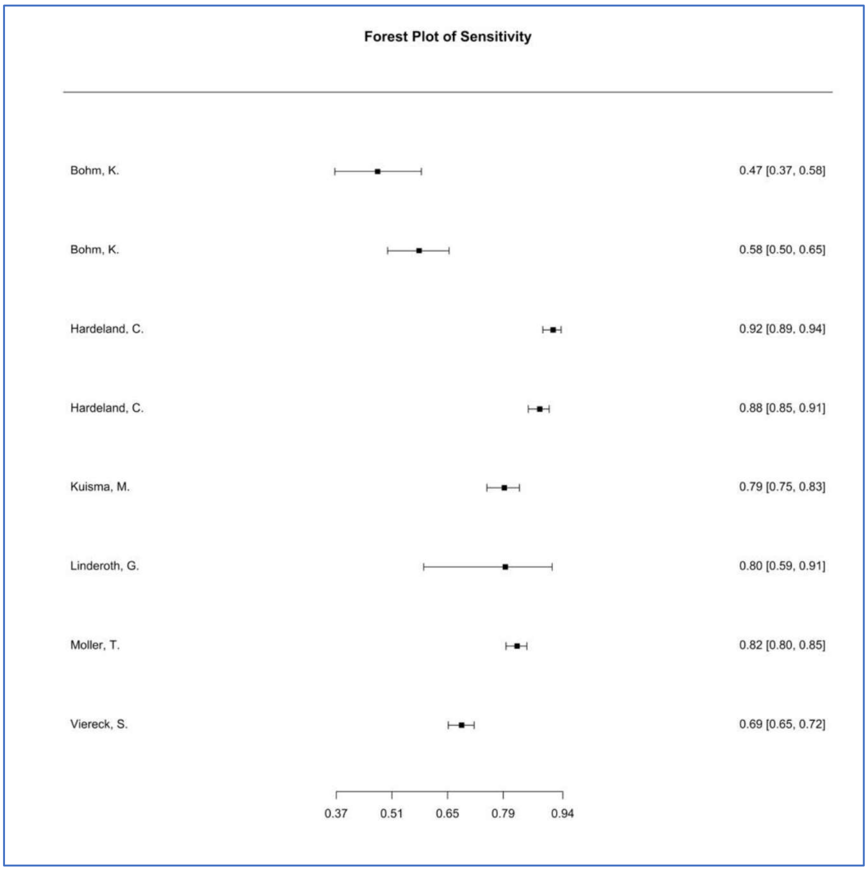
Figure 4

Figure 4: Sensitivity and specificity based on dispatch criteria

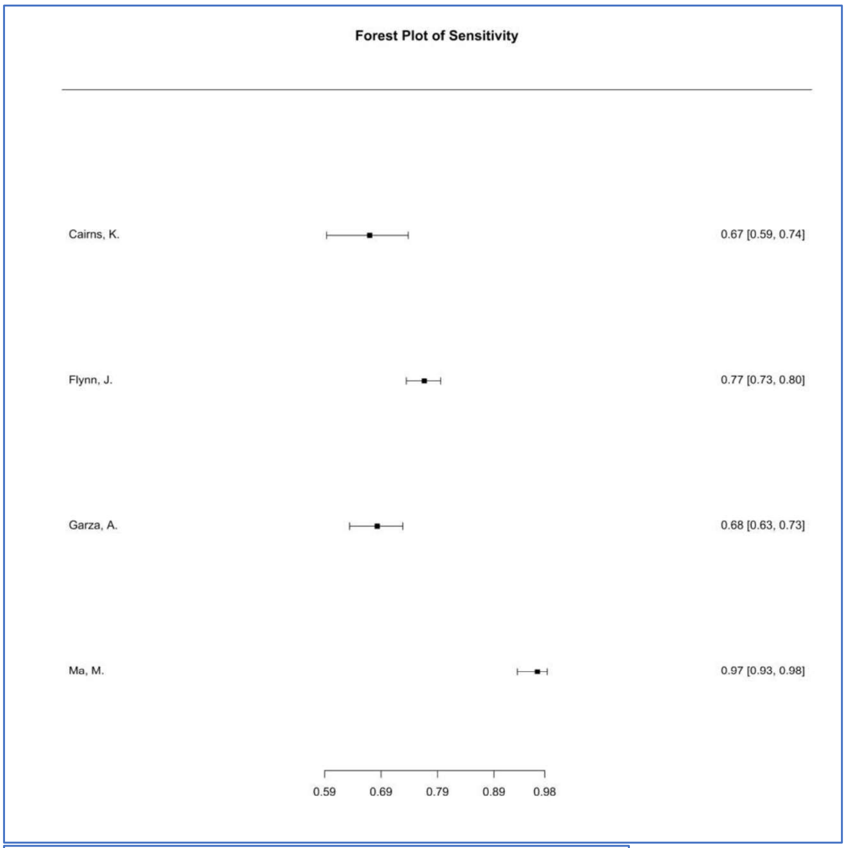


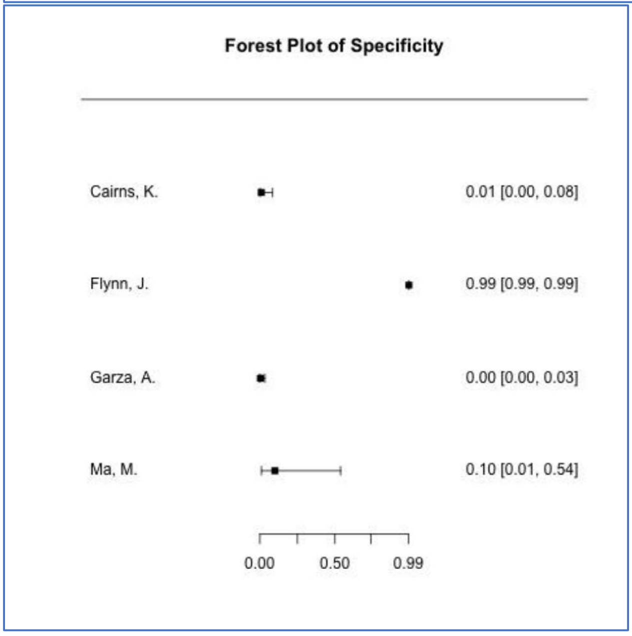


4a: Criteria based dispatch

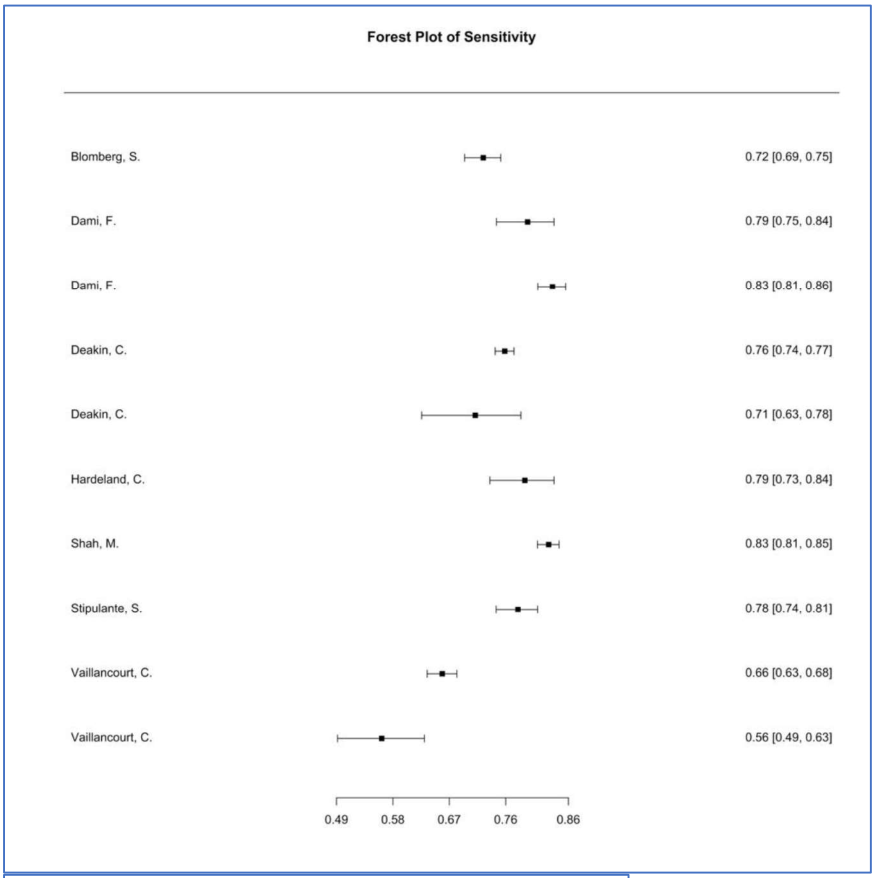


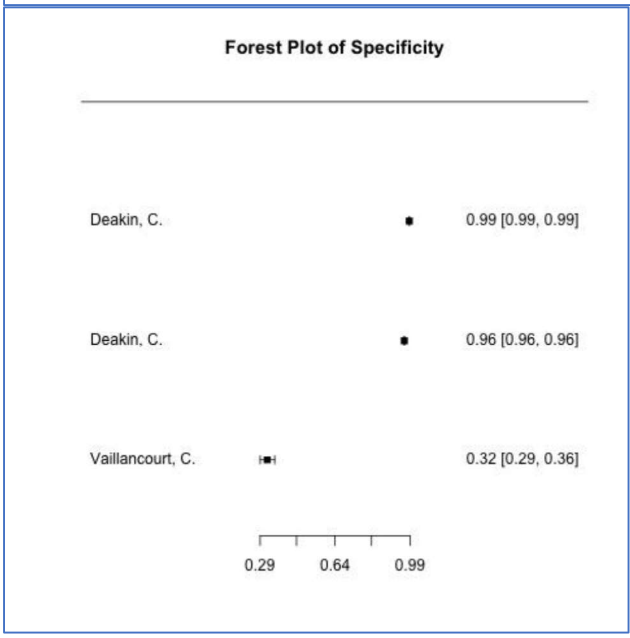
4b: Norwegian Medical Index





4c: Advanced Medical Priority Dispatch System

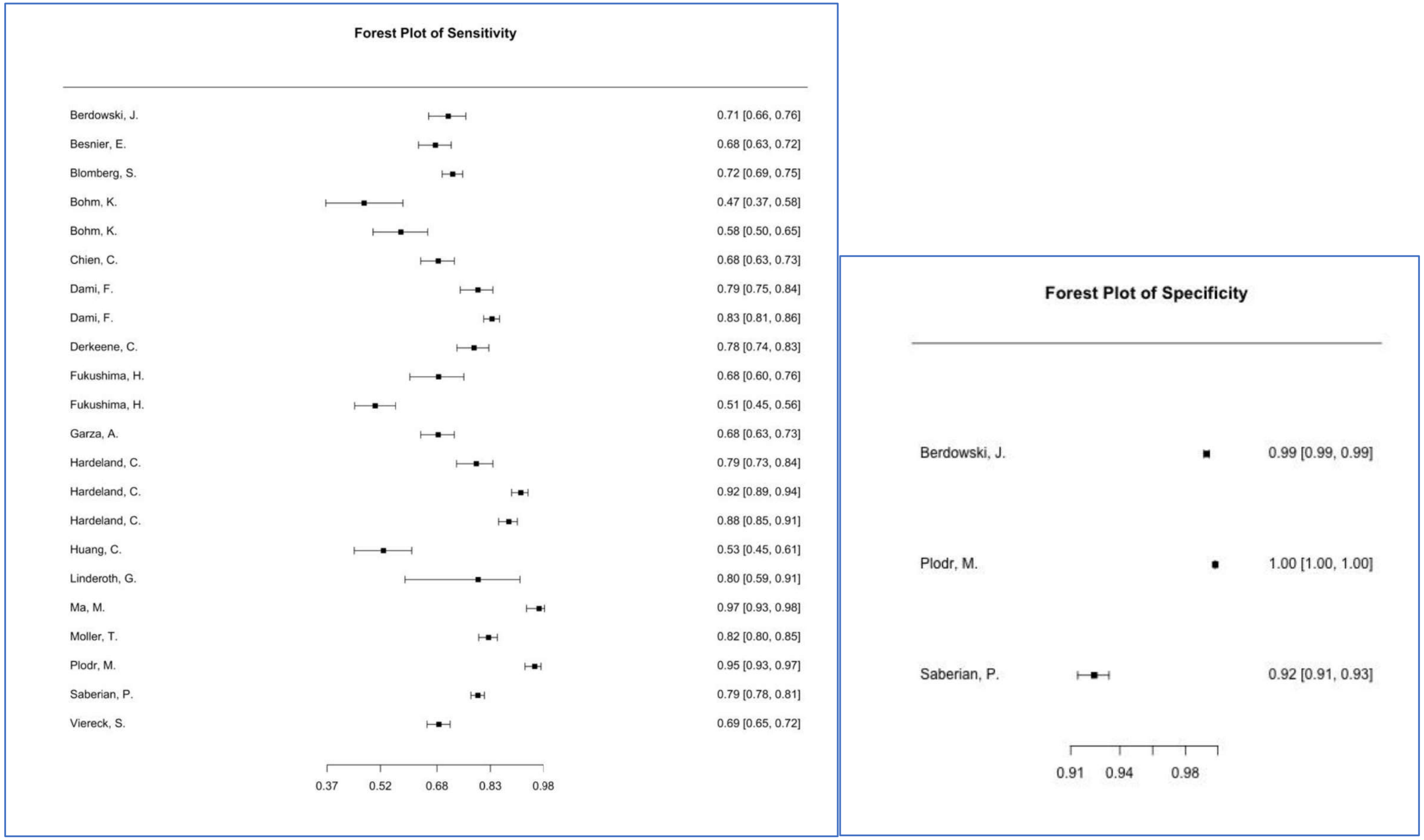




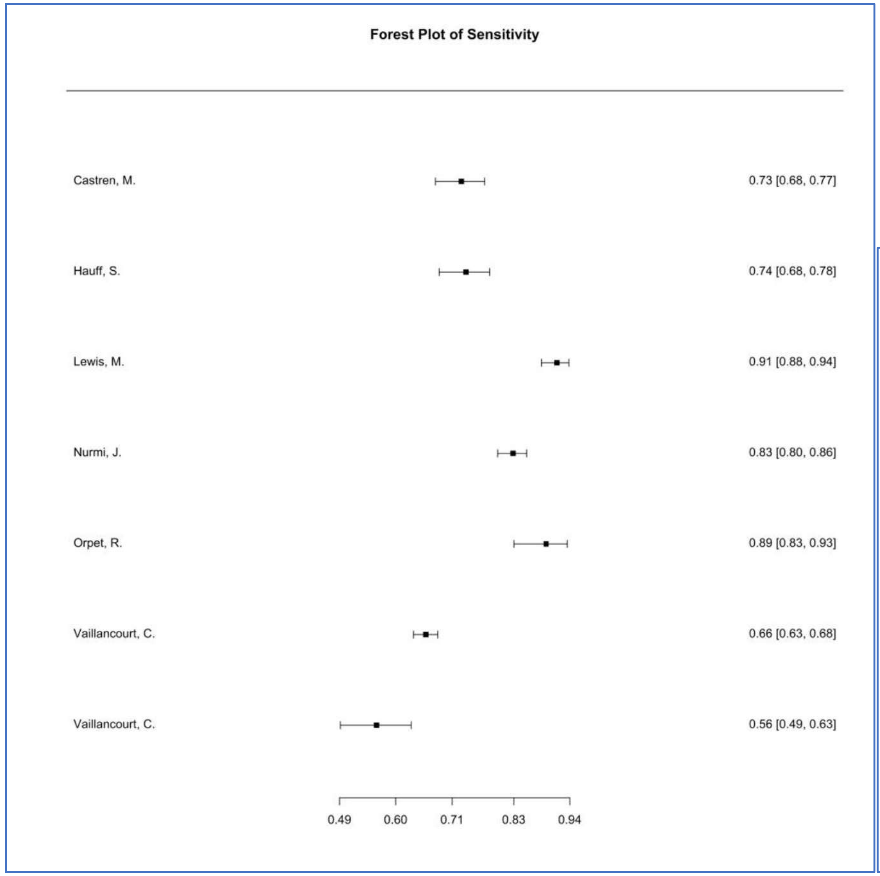
4d: Other dispatch criteria

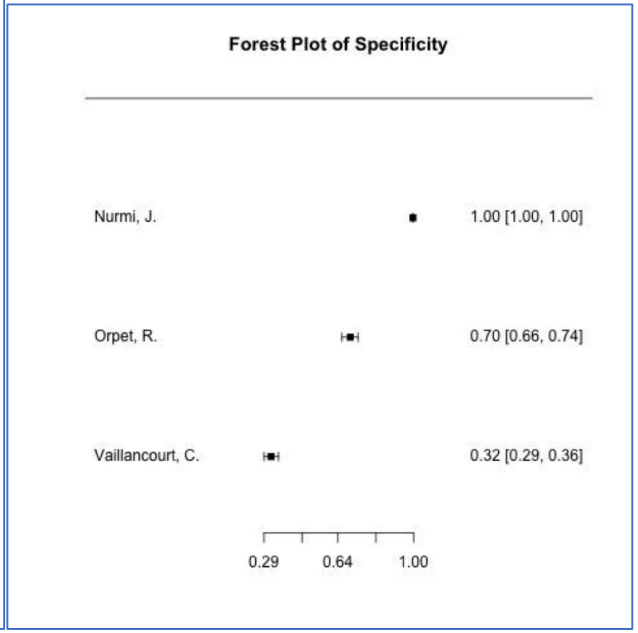
Figure 5

Figure 5: Sensitivity and Specificity based on dispatcher education

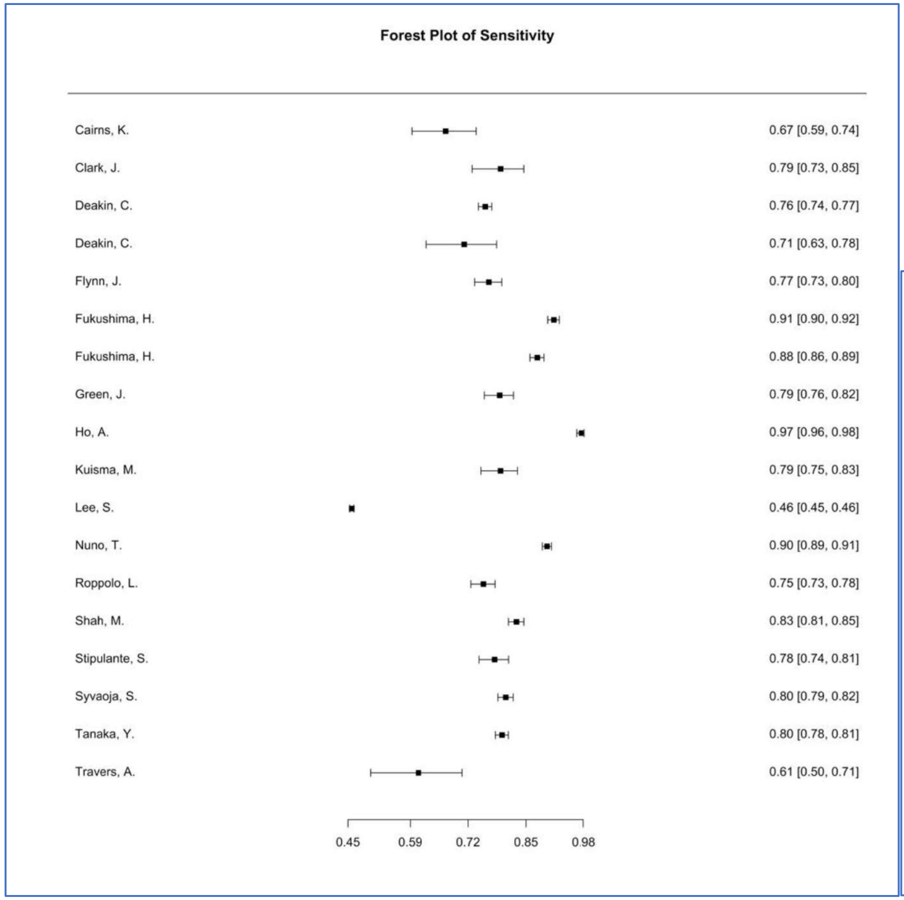


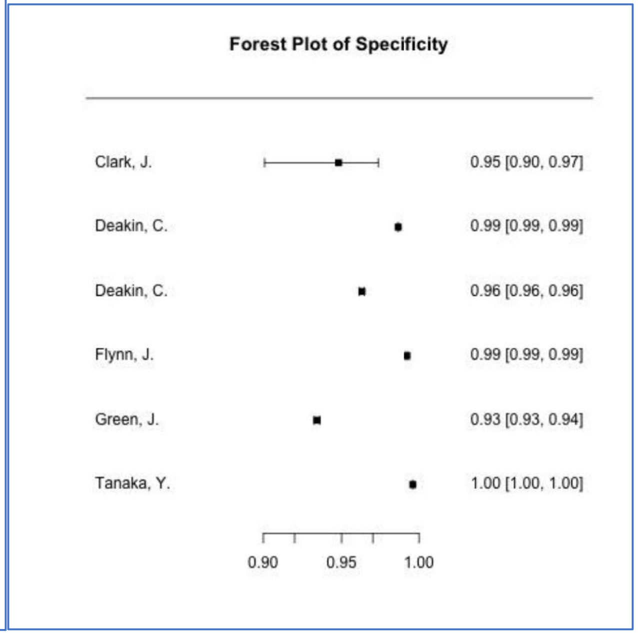
5a: Dispatchers with medical education





5b: Dispatchers without medical education





5c: Dispatchers with unknown education

Conflict of Interest

Some of the authors (T.Olasveengen) and Task Force collaborators (C Vaillancourt, M Castren, Judith Finn) have published manuscripts related to dispatcher recognition of cardiac arrest which are included in this review. T.O. has received research funding from Zoll Foundation and Laerdal Foundation. No other authors report any financial conflicts of interests and none of the authors have academic conflicts related to ongoing or planned trials.

Credit Author Statement

All authors were involved in the conception and design of the study. IRD, KC, and GG were involved in the screening of articles and performing the statistical analysis. All authors were involved in interpretation of the data. IRD and KC were involved in drafting of the manuscript. All authors were involved in critically revising the manuscript and provided intellectual contribution to the final manuscript. All authors provided final approval of the manuscript for submission.