WORKSHEET for Evidence-Based Review of Science for Emergency Cardiac Care

Worksheet author(s)

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Clinical question.

BLS-020(B) In adult and pediatric patients in cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of feedback regarding the mechanics of CPR quality (e.g. rate and depth of compressions and/or ventilations) (I) compared with no feedback (C), improve any outcomes (eg. ROSC, survival) (O)?

Is this question addressing an intervention/therapy, prognosis or diagnosis? Intervention
State if this is a proposed new topic or revision of existing worksheet: 2005 WS 190A, 190B. Worksheet 190A identified "Hypothesis 2: Audio prompts or other forms of feedback that guide action sequences and timing of chest compressions and ventilations during cardiac arrest events will aid rescuers in performing CPR skills"

Conflict of interest specific to this question

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? No

Search strategy (including electronic databases searched).

1) OVID Medline/Pubmed was searched using the following strategies:
MeSH headings "heart arrest" OR "CPR" OR "ventricular fibrillation" OR "cardiopulmonary resuscitation" AND keywords "feedback" or "feedback devices" [yielded 90 abstracts]
MeSH headings "heart arrest" OR "CPR" OR "ventricular fibrillation" OR "cardiopulmonary resuscitation" AND keywords "quality" [yielded 935 abstracts]
MeSH headings "heart arrest" OR "CPR" OR "ventricular fibrillation" OR "cardiopulmonary resuscitation" AND keywords "quality" AND "feedback devices" [yielded 14 abstracts]

2) Forward search on Google Scholar [yielded two additional articles in press]

3) Cochrane Database of Systematic Reviews searched using defined terms [yielded no additional articles]

4) AHA EndNote Library X [yielded no additional articles]

5) Hand search of references identified in applicable articles [yielded two additional articles]

• State inclusion and exclusion criteria

Exclusion criteria:
1) Abstract only studies, editorials and letters to editor and non-peer-reviewed articles were excluded from this review.
2) A search limit of articles published between 1966 through January 2010 was used for online database searches; however, hand searches of references from applicable articles included any applicable study regardless of publication year.
3) Studies where feedback, in the form of debriefing, was provided to the rescuers after the resuscitation event and not during the event were excluded from this review.
4) For the purpose of this worksheet, "feedback" will be operationally defined as real-time invasive and non-invasive technologies used for the purpose of measuring one or more aspects of CPR performance during a human or animal cardiac arrest event. This worksheet will address non-invasive feedback technologies, (i.e. transthoracic impedance, force transducers, accelerometers, metronomes and prompt devices). Invasive physiologic technologies for providing feedback regarding the quality of CPR will be addressed in ALS WS 010A, B.
5) Mannequin studies incorporating feedback/prompt technologies for CPR skills acquisition or skill quality improvement were not included for this review as they are addressed in EIT WS 005A, B.

Inclusion criteria:
1) All peer reviewed studies examining the use of non-invasive, real-time feedback technologies to measure and guide rescuer CPR performance during cardiac arrest events were reviewed for this worksheet.

• Number of articles/sources meeting criteria for further review:

This search strategy yielded 142 articles for review; of those, 23 articles met the inclusion criteria for this review.

Supporting:
LOE 2: Chiang, 2005, 297; Kern, 1992, 145; Berg, 1994, 35
LOE 3: Abella, 2007, 54; Kramer-Johansen, 2006, 283; Niles, 2009, 553; Fletcher, 2008, 127
LOE 4: Edelson, 2008, 1063; Risdal, 2007, 2237; Gruben, 1990, 204; Pytte, 2007, 70
LOE 5: Barsan, 1981, 135; Milander, 1995,708

Neutral:
LOE 3: Kramer-Johansen, 2006, 283 (ventilation parameters); Olasveengen, 2007, 427;
LOE 4: Sutton, 2009, 494
LOE 5: Abella, 2005, 310; Wik, 2005, 299; Odegaard, 2007, 127

Opposing:
LOE 4: Edelson, 2009, *in press*
LOE 5: Nishisaki, 2009, 540; Perkins, 2009, 79

Summary of evidence

Evidence Supporting Clinical Question

Good		Chiang, 2005, 297-301[E, h]	Abella, 2007, 54-61[A, C, E,v,c] Kramer-Johansen, 2006, 283, [E, c]	Edelson, 2008, 1063-9[A,C,E,,v,c]	Barsan, 1981, 135-7 [*E, h*]
Fair		Kern, 1992, 145-9[E, h]	Niles, 2009, 553-7[E, c]	Risdal, 2007, 2237-45[E, v] Gruben, 1990, 204-10[E,c]	Milander, 1995, 708-13[E, a, c, v]
Poor		Berg, 1994, 35-40[E, h]	Fletcher, 2008, 127-34[E, c]	Pytte, 2007, 770[E, v]	
	1	**2**	**3**	**4**	**5**
Level of evidence					

A = Return of spontaneous circulation
B = Survival of event
(v) = ventilation parameters

C = Survival to hospital discharge
D = Intact neurological survival
(c) = compression parameters

E = Other endpoint (v, c, h)
Italics = Animal studies
(h) = haemodynamics

Evidence Neutral to Clinical question

Good			Olasveengen, 2007, 427-33[E, v,c] Kramer-Johansen, 2006, 283-92 [A, B, E, v, c]	Sutton, 2009, 494-9 [E, c]	Abella, 2005, 305-10 [E, c,v] Wik, 2005, 299-304 [A,B,C,D, E , c]
Fair					Odegaard, 2007, 127-34 [E, c]
Poor					
	1	**2**	**3**	**4**	**5**
Level of evidence					

A = Return of spontaneous circulation
B = Survival of event
(v) = ventilation parameters

C = Survival to hospital discharge
D = Intact neurological survival
(c) = compression parameters

E = Other endpoint (v, c, h)
Italics = Animal studies
(h) = haemodynamics

Evidence Opposing Clinical Question

Good				Edelson, 2009, in press, [E, v]	Nishisaki, 2009, 540-5; Perkins, 2009, 79-82[E, c]
Fair					
Poor					
	1	**2**	**3**	**4**	**5**
Level of evidence					

A = Return of spontaneous circulation
B = Survival of event
(v) = ventilation parameters

C = Survival to hospital discharge
D = Intact neurological survival
(c) = compression parameters

E = Other endpoint (v, c, h)
Italics = Animal studies
(h) = haemodynamics

REVIEWER'S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:

There are no published randomized controlled trials (RCTs) exploring the efficiency of CPR feedback devices in human cardiac arrests. Several studies have demonstrated an improvement in CPR quality performance measures when real-time performance feedback is given to the provider during a resuscitation event. However, to date, there is no definitive evidence of improvement in patient survival as a result of feedback guided performance.

Evidence from two good LOE 5 studies in adults (Abella, 2005, 305; Wik, 2005, 299) demonstrates unprompted CPR is frequently of poor quality in both in-hospital and out-of-hospital settings. A case series of 176 adult out-of-hospital adult cardiac arrest patients used accelerometer and thoracic impedance technologies to assess compression and ventilation quality (Wik 2005). Findings indicate chest compressions were not completed about half the time and most compressions were too shallow. A prospective observational study of 67 in-hospital cardiac arrests yielded similar results (Abella, 2005). CPR quality parameters (compression depth and rate, ventilation rate, no-flow fraction) were measured and compared against international standards. Demonstrating that non-prompted, conventional CPR is frequently inconsistent and below set standard, the researchers concluded that utilizing CPR feedback and prompt devices during cardiac arrest events may improve performance and potentially increase survival.

Evidence suggests feedback/prompt devices may improve the quality of CPR performance on several discreet measures (ventilation rate, ETCO2, compression rate, depth, and recoil). Eleven studies investigated real-time CPR performance feedback during actual cardiac arrest events in both in-hospital and out-of-hospital settings. Evidence from two LOE 2 studies in adults (Chiang, 2005, 297; Kern, 1992, 145) and one LOE 2 in children (Berg, 1994, 35) shows improvement in end-tidal CO2 measures and consistent chest compression rates when feedback was provided from audio prompts (metronomes or sirens). In a good LOE 2 study Chiang (2005) completed a two phase study to determine if real-time feedback during resuscitation events was effective in correcting substandard CPR performance. They first assessed CPR provider skills and identified inadequate number of chest compressions per minute, lack of re-oxygenation during prolonged intubation attempts and unnecessary hands-off periods as the three most prominent deficiencies. During phase II they compared the performance of providers receiving real-time audio feedback (N = 13) to those who did not (N= 17) during 30 in-hospital resuscitation events. A metronome recording at 100 beats/minute and a siren sound every 20 seconds provided audio feedback. The group receiving feedback showed significant improvement in two of three performance targets; the total hands-off time during CPR was significantly reduced (164 +/- 94 s versus 273 +/- 153 s, $P < 0.05$) and the proportion of intubation attempts taking under 20 s was significantly decreased (56.3% versus 10%, $P < 0.05$).

Four LOE 3 studies (Abella, 2007, 54; Kramer-Johansen, 2006, 283; Niles 2009, 553; Fletcher 2008, 127) and two LOE 4 studies (Edelson, 2008, 1063; Gruben, 1990, 204) suggests real-time feedback from force transducers and accelerometers can be used to improve CPR quality parameters including compression depth, rate and complete chest recoil. Kramer-Johansen, et al, introduced the Q-CPR monitor/defibrillator feedback device to the pre-hospital environment. Consecutive adult cardiac arrest events were enrolled in the non-feedback group between 3/02 through 10/03 (N = 176) and the feedback group between 10/03 through 9/04 (N = 108); CPR quality parameters were measured. The average depth of compression increased from 34 (+/-9) mm to 38 (+/- 6) mm (95% CI 2-6, P< 0.001) with feedback. The median percentage of compressions within the recommended standard depth (38-51 mm) increased from 24% at baseline to 53% with feedback (P> 0.001). The mean compression rate decreased from 121 (+/- 18) min, prior to feedback to 109 (+/- 12) min (-1) with feedback (95% CI difference -16, -9, P = 0.001. There were no significant changes in fraction of no-flow time, the mean number of ventilations delivered per minute or survival between the two groups (Kramer-Johansen, 2006).

Abella, et al, also used the Q-CPR device to provide real-time feedback to rescuers. This before/after study included all inpatient cardiac arrest from 12/04 to 12/05 (N=55) as compared to pre-intervention (historical control) 12/2002 to 4/2004 (N=101). The Q-CPR monitor/defibrillator unit with CPR sensing and feedback capabilities was used to provide real-time feedback to rescuers during the intervention period. There was a modest, yet statistically insignificant, improvement in the mean values of CPR parameters including chest compression rate (104+/-18 to 100+/-13 min(-1); test of means, p=0.16; test of variance, p=0.003) and ventilation rate (20+/-10 to 18+/-8 min(-1); test of means, p=0.12; test of variance, p=0.04). There were no statistically significant improvements between the groups in either return of spontaneous circulation or survival to hospital discharge.

Evidence from two (LOE 4) case series (Risdal, 2007, 2237; Pytte, 2007, 770) demonstrates that changes in transthoracic impedance may be used to provide a consistent and appropriate ventilation rate or detect esophageal intubation. A fair LOE 4 case series study (Risdal, 2007) of cardiac arrest patients used thoracic impedance changes as a method of real-time feedback to detect ventilation during CPR. During chest compressions, the detection system achieved a mean positive predictive value of 94.8% and sensitivity of 88.7%. Pytte (2007) reports on two cases where transthoracic impedance monitoring detected inadequate ventilation in intubated, cardiac arrest patients. Inadequate ventilation in both of these cases was the direct result of a misplaced endotrachael tube.

All of these studies suggest improvement in one or more CPR quality measures when real-time performance feedback is provided to the rescuer. However, there are no studies to date that demonstrate a significant improvement in patient survival related to the use of CPR feedback devices during actual cardiac arrest events.

Device Limitations

The potential risks and limitations of using feedback technologies in cardiac arrest events have been identified in three studies (Edelson, 2009, in press; Nishisaki, 2009, 540; Perkins, 2009, 79; Cho, 2009, 600). Two (LOE 5) good quality mannequin studies (Nishisaki, 2009, 540; Perkins, 2009, 79) demonstrate the potential for overestimating compression depth if compressions are performed (with or without a backboard) on a soft surface. One good LOE 4 case series study (Edelson, 2009, in press) suggests capnography and chest-wall impedance algorithms may be inaccurate for determining ventilation rate. The mean ventilation rate from 37 cardiac arrests was manually calculated and compared to impedance and capnography measures. The mean ventilation rate was 13.3Â±4.3/min in comparison to the defibrillator's impedance-based algorithm rate of 11.3Â±4.4/min (p=0.0001) and the capnography rate of 11.7Â±3.7/min (p=0.0009). Hyperventilation is both common and detrimental during cardiopulmonary resuscitation (CPR). Hyperventilation during CPR is common and accurate feedback technology may prove a valuable tool in regulating ventilation rates. A good LOE 5 mannequin study (Nishisaki, 2009, 540) based on data reconstructed from 12 pediatric in-hospital cardiac arrest events. After controlling for mattress compression, chest compressions meeting the standards for depth (38-51 mm) decreased from 88.4 to 31.8% on ICU beds (P <0.001) and 86.3 to 64.7% on stretcher beds (P < 0.001), indicating that compressions performed on a non-rigid surface may not be deep enough.

Acknowledgements:

Citation List

Abella BS, Alvarado JP, Myklebust H, Edelson DP, Barry A, O'Hearn N, et al. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. JAMA. **2005** Jan 19;293(3):305-10.

LOE 4: Quality good; neutral. Prospective observational study. N = 67, in-hospital cardiac arrest patients. CPR quality parameters (compression depth and rate, ventilation rate, no-flow fraction) were measured and compared against standard. Study demonstrated that non-prompted, conventional CPR is frequently inconsistent and below set standard.

Abella BS, Edelson DP, Kim S, Retzer E, Myklebust H, Barry AM, et al. CPR quality improvement during in-hospital cardiac arrest using a real-time audiovisual feedback system. Resuscitation. **2007** Apr;73(1):54-61.

LOE 3: Quality good; supportive. This before/after study included all inpatient cardiac arrest from 12/04 to 12/05 (N=55) as compared to pre-intervention (historical control) 12/2002 to 4/2004 (N=101). The Q-CPR monitor/defibrillator unit with CPR sensing and feedback capabilities was used to provide real-time feedback to rescuers during the intervention period. There was a modest, yet statistically insignificant, improvement in the mean values of CPR parameters including chest compression rate (104+/-18 to 100+/-13 min(-1); test of means, p=0.16; test of variance, p=0.003) and ventilation rate (20+/-10 to 18+/-8 min(-1); test of means, p=0.12; test of variance, p=0.04). There were no statistically significant improvements between the groups in either return of spontaneous circulation or survival to hospital discharge. Real-time CPR-sensing and feedback technology may serve as a useful adjunct for rescuers during resuscitation efforts.

Barsan WG, Levy RC. Experimental design for study of cardiopulmonary resuscitation in dogs. Ann Emerg Med. **1981** Mar;10(3):135-7.

LOE 5: Quality good; Supportive. Animal study (canine model) comparing closed manual chest compressions with mechanical chest compressions and open chest cardiac massage. A metronome was used to obtain a consistent chest compression rate and arterial blood pressure measured cardiac output. Findings correlated a consistent compression rate with improved cardiac output.

Berg RA, Sanders AB, Milander M, Tellez D, Liu P, Beyda D. Efficacy of audio-prompted rate guidance in improving resuscitator performance of cardiopulmonary resuscitation on children. Acad Emerg Med. **1994** 1994 Jan-Feb;1(1):35-40.

LOE 2: Quality poor, supporting. Prospective study . N =6, pediatric patients with nontraumatic cardiac arrest. ETCO2 measured prior to audiotape (metronome) at compression rates of 100/min and 140/min x 1 minute. No difference in outcome measures with audiotape at 100/min & 140/min; both were superior to pre-audio-prompted group. Audio- prompted rate guidance during CPR in children resulted in higher PETCO2, suggesting improved CPR performance.

Chiang WC, Chen WJ, Chen SY, Ko PC, Lin CH, Tsai MS, et al. Better adherence to the guidelines during cardiopulmonary resuscitation through the provision of audio-prompts. Resuscitation. **2005** Mar;64(3):297-301.

LOE 2: Quality good; supportive. Before/after study. This study consisted for 2 stages. Stage 1 identified rescuer deficiencies with CPR quality measures (no-flow time, low chest compression rate, oxygenation during ventilation). Phase 2 used an audio-prompt device to set compression rate (100b/sec) during actual cardiac arrest events. Intervention group showed significant improvement in CPR quality measures.

Edelson D, P. , Eilevstjonn J, Weidman E, K. , Retzer E, Van den Hoek T, L. , Abella B, S. . Capnography and chest-wall impedance algorithms for ventilation detection during cardiopulmonary resuscitation. Resuscitation. **2009**.

LOE 4: Quality Good; Opposing. This case series study of 37 consecutive in-patient cardiac arrests examined the accuracy of capnography and chest-wall impedance algorithms in determining hyperventilation during CPR. Both algorithms understimated the ventilation rate and there was no significant difference in sensitivity and positive predictive value between the two methods.

Edelson DP, Litzinger B, Arora V, Walsh D, Kim S, Lauderdale DS, et al. Improving in-hospital cardiac arrest process and outcomes with performance debriefing. Arch Intern Med. **2008** May 26;168(10):1063-9.

LOE 4: Quality good; supportive. This is a case series of 224 cardiac arrest patients in a hospital setting. The Q-CPR monitor/defibrillator feedback device was used to measure CPR quality parameters (ventilation rate, compression rate and depth, no-flow time. CPR quality was improved with implementation of CPR feedback techniques.

Fletcher D, Galloway R, Chamberlain D, Pateman J, Bryant G, Newcombe RG. Basics in advanced life support: A role for download audit and metronomes. Resuscitation. **2008**;78(2):127-34.

LOE 3: Quality poor; supporting. This before/after observational study examined the role of audio feedback (metronomes) in improving the quality of CPR performance in pre-hospital cardiac arrest. Audio feedback during cardiac arrest was introduced to ambulance crews; CPR parameters related to compressions were measured and compared to pre-intervention data. Researchers found improvements in CPR performance, compression rate and no-flow (hands-off) time, and an improvement in patient outcomes (survival to discharge). Several potential confounders, (Hawthorne effect, change in CPR protocol, data gathering issues, etc), are evident.

Gruben KG, Romlein J, Halperin HR, Tsitlik JE. System for mechanical measurements during cardiopulmonary resuscitation in humans. IEEE Trans Biomed Eng. **1990** Feb;37(2):204-10.

LOE 4: Quality fair; supporting. This case series study utilizes a position-sensing arm device which measures both force and acceleration at the sternum. Real-time feedback via an audible tone was used to guide rescuer performance of compression rate and depth. Both invasive (central venous and aortic pressures) and non-invasive physiologic measures were obtained and reported.

Kern KB, Sanders AB, Raife J, Milander MM, Otto CW, Ewy GA. A study of chest compression rates during cardiopulmonary resuscitation in humans: the importance of rate-directed chest compressions. Arch Intern Med. **1992** Jan;152(1):145-9.

LOE 2: Quality fair; supportive. Prospective, cross-over study using concurrent controls for 23 in-hospital cardiac arrest events. Audible tone feedback during chest compressions was provided to rescuers performing CPR. ETCO2 and compression quality parameters were measured and indicated an improvement in CPR performance when real-time feedback was provided to rescuers.

Kramer-Johansen J, Myklebust H, Wik L, Fellows B, Svensson L, Sorebo H, et al. Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective interventional study. Resuscitation. **2006** Dec;71(3):283-92.

LOE 3: Quality, good; supporting. This prospective, non-randomized study, introduced the Q-CPR monitor/defibrillator feedback device to the pre-hospital environment. Consecutive adult cardiac arrest events were enrolled in the non-feedback group between 3/02 through 10/03 (N = 176) and the feedback group between 10/03 through 9/04 (N = 108); CPR quality parameters were measured. The average depth of compression increased from 34 (+/-9) mm to 38 (+/- 6) mm (95% CI 2-6, P< 0.001) with feedback. The median percentage of compressions within the recommended standard depth (38-51 mm) increased from 24% at baseline to 53% with feedback (P> 0.001). The mean compression rate decreased from 121 (+/- 18) min, prior to feedback to 109 (+/- 12) min (-1) with feedback (95% CI difference -16, -9, P = 0.001. There were no significant changes in fraction of no-flow time or the mean number of ventilations delivered per minute or survival between the two groups.

Milander MM, Hiscok PS, Sanders AB, Kern KB, Berg RA, Ewy GA. Chest compression and ventilation rates during cardiopulmonary resuscitation: the effects of audible tone guidance. Acad Emerg Med. **1995** Aug;2(8):708-13.

LOE 5, quality fair; supportive. Part I of this two part study was strictly observational with no interventions. Researchers counted compression and ventilation rates during in-hospital cardiac arrest events and found rescuers were not in compliance with national CPR performance standards the majority of the time. Part II of this study incorporated a porcine model in a before/after design to evaluate the CPR performance of 41 volunteers. CPR performance with and without feedback from an audio prompt (metronome) was measured using invasive and non-invasive parameters including chest compression rate, ETCO2, arterial and venous blood pressures, and coronary perfusion pressures. Study findings indicate a significant improvement in chest compression rates and ETCO2 levels with audio prompt feedback.

Niles D, Nysaether J, Sutton R, Nishisaki A, Abella BS, Arbogast K, et al. Leaning is common during in-hospital pediatric CPR, and decreased with automated corrective feedback. Resuscitation. **2009** May;80(5):553-7.

LOE 3: Quality fair; supportive.

Nishisaki A, Nysaether J, Sutton R, Maltese M, Niles D, Donoghue A, et al. Effect of mattress deflection on CPR quality assessment for older children and adolescents. Resuscitation. **2009** May;80(5):540-5.

LOE 5: Quality good; opposing. In this manikin study, accerometer data from 12 in-hospital pediatric cardiac arrest events were reconstructed with ICU beds and stretcher beds. After controlling for matress compression, chest compressions meeting the standards for depth (38-51 mm) decreased from 88.4 to 31.8% on ICU beds (P <0.001) and 86.3 to 64.7% on stretcher beds (P < 0.001), indicating that compressions performed on a non-rigid surface may not be deep enough.

Odegaard S, Kramer-Johansen J, Bromley A, Myklebust H, Nysaether J, Wik L, et al. Chest compressions by ambulance personnel on chests with variable stiffness: abilities and attitudes. Resuscitation. **2007** Jul;74(1):127-34.

LOE 5: Quality poor; neutral

Olasveengen TM, Tomlinson AE, Wik L, Sunde K, Steen PA, Myklebust H, et al. A failed attempt to improve quality of out-of-hospital CPR through performance evaluation. Prehosp Emerg Care. **2007** Oct-Dec;11(4):427-33.

LOE 3: Quality good; neutral. N= 85 OOHCA, non-randomized; N= 39, historical control. Intervention = real-time automated verbal and visual feedback (CPR-PE); chest compression depth within range (38-51 mm) increased from 31% to 61%.

Perkins GD, Kocierz L, Smith SC, McCulloch RA, Davies RP. Compression feedback devices over estimate chest compression depth when performed on a bed. Resuscitation. **2009** Jan;80(1):79-82.

LOE 5: Quality good; opposing.

Risdal M, Aase SO, Stavland M, Eftestol T. Impedance-based ventilation detection during cardiopulmonary resuscitation. IEEE Trans Biomed Eng. **2007** Dec;54(12):2237-45.

LOE 4: Quality fair; supporting. Case series study using thoracic impedance changes as a method of real-time feedback to detect ventilation during CPR. During chest compressions, the detection system achieved a mean positive predictive value of 94.8% and sensitivity of 88.7%.

Sutton RM, Niles D, Nysaether J, Abella BS, Arbogast KB, Nishisaki A, et al. Quantitative analysis of CPR quality during in-hospital resuscitation of older children and adolescents. Pediatrics. **2009** Aug;124(2):494-9.

LOE 4: Quality good; neutral. Prospective. observation study of 18 pediatric, in-hospital cardiac arrest patients. Healthcare providers in the setting participate in a bedside CPR training refresher to keep CPR skills current. CPR recording/feedback defibrillators are used to provide real-time feedback during a cardiac arrest event. Despite the initiatives, CPR quality measures frequently failed to meet standards. Chest compressions were found to be shallow (< 38 mm) in 27.2% of total compressions and excessive leaning was detected in 23.4% of compressions.

Wik L, Kramer-Johansen J, Myklebust H, Sorebo H, Svensson L, Fellows B, et al. Quality of cardiopulmonary resuscitation during out-of-hospital cardiac arrest. Jama. **2005** Jan 19;293(3):299-304.

LOE 5: Quality good; neutral. This case series on 176 adult out -of hospital adult cardiac arrest patients used accelerometer and thoracic impedance technologies to assess compression and ventilation quality measures. Findings indicate chest compressions not completed about half of the time and most compressions were too shallow.