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Part 7: CPR Techniques and Devices:

2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

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Keywords

cardiac arrest; cardiopulmonary resuscitation; emergency; ventricular fibrillation

Over the past 25 years a variety of alternatives to conventional manual CPR have been developed in an effort to enhance perfusion during attempted resuscitation from cardiac arrest and to improve survival. Compared with conventional CPR, these techniques and devices typically require more personnel, training, and equipment, or they apply to a specific setting. Application of these devices has the potential to delay or interrupt CPR, so rescuers should be trained to minimize any interruption of chest compressions or defibrillation and should be retrained as needed. Efficacy for some techniques and devices has been reported in selected settings and patient conditions; however, no alternative technique or device in routine use has consistently been shown to be superior to conventional CPR for out-of-hospital basic life support. In this section, no class of recommendation is made when there is insufficient evidence of benefit or harm, particularly if human data are extremely limited. For those devices assigned a 2005 Class of Recommendation other than Indeterminate, Classes of Recommendation were assigned when possible using the same criteria applied throughout this document (see Part 1: "Executive Summary" and Part 2: "Evidence Evaluation").

Whenever these devices are used, providers should monitor for evidence of benefit versus harm. The experts are aware of several clinical trials of the devices listed below that are under way and/or recently concluded, so readers are encouraged to monitor for the publication of additional trial results in peer-reviewed journals and AHA scientific advisory statements.

CPR Techniques

High-Frequency Chest Compressions

High-frequency chest compression (typically at a frequency >120 per minute) has been studied as a technique for improving resuscitation from cardiac arrest.[1] The sparse human data have demonstrated mixed results. One clinical trial including 9 patients[2] and another including 23 patients[3] showed that a compression frequency of 120 per minute improved hemodynamics compared to conventional chest compressions; no change in clinical outcome was reported. These *2010 AHA Guidelines for CPR and ECC* recommend compressions at a rate of at least 100/min. There is insufficient evidence to recommend the routine use of high-frequency chest compressions for cardiac arrest. However, high-frequency chest compressions may be considered by adequately trained rescue personnel as an alternative (Class IIb, LOE C).

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Open-Chest CPR

In open-chest CPR the heart is accessed through a thoracotomy (typically created through the 5th left intercostal space) and compression is performed using the thumb and fingers, or with the palm and extended fingers against the sternum. Use of this technique generates forward blood flow and coronary perfusion pressure that typically exceed those generated by closed chest compressions.

There are few human studies comparing open-chest CPR to conventional CPR in cardiac arrest and no prospective randomized trials. Several studies of open-chest CPR have demonstrated improved coronary perfusion pressure and/or return of spontaneous circulation (ROSC) for both the inhospital (eg, following cardiac surgery)[4 – 6] and out-of-hospital environments.[7–10]

Several small case series of cardiac arrest patients treated with thoracotomy and open-chest CPR after blunt[11,12] or penetrating trauma[12–14] reported survivors with mild or no neurological deficit.

There is insufficient evidence of benefit or harm to recommend the routine use of open-chest CPR. However, open-chest CPR can be useful if cardiac arrest develops during surgery when the chest or abdomen is already open, or in the early postoperative period after cardiothoracic surgery (Class IIa, LOE C). A resuscitative thoracotomy to facilitate open-chest CPR may be considered in very select circumstances of adults and children with out-of-hospital cardiac arrest from penetrating trauma with short transport times to a trauma facility (Class IIb, LOE C).[15,16]

Interposed Abdominal Compression-CPR

The interposed abdominal compression (IAC)-CPR is a 3-rescuer technique (an abdominal compressor plus the chest compressor and the rescuer providing ventilations) that includes conventional chest compressions combined with alternating abdominal compressions. The dedicated rescuer who provides manual abdominal compressions will compress the abdomen midway between the xiphoid and the umbilicus during the relaxation phase of chest compression. Hand position, depth, rhythm, and rate of abdominal compressions are similar to those for chest compressions and the force required is similar to that used to palpate the abdominal aorta. In most reports, an endotracheal tube is placed before or shortly after initiation of IAC-CPR. IAC-CPR increases diastolic aortic pressure and venous return, resulting in improved coronary perfusion pressure and blood flow to other vital organs.

In 2 randomized in-hospital trials, IAC-CPR performed by trained rescuers improved short-term survival[17] and survival to hospital discharge[18] compared with conventional CPR for adult cardiac arrest. The data from these studies were combined in 2 positive meta-analyses.[19,20] However, 1 randomized controlled trial of adult out-of-hospital cardiac arrest[21] did not show any survival advantage to IAC-CPR. Although there were no complications reported in adults,[19] 1 pediatric case report[22] documented traumatic pancreatitis following IAC-CPR.

IAC-CPR may be considered during in-hospital resuscitation when sufficient personnel trained in its use are available (Class IIb, LOE B). There is insufficient evidence to recommend for or against the use of IAC-CPR in the out-of-hospital setting or in children.

“Cough” CPR

“Cough” CPR describes the use of forceful voluntary coughs every 1 to 3 seconds in conscious patients shortly after the onset of a witnessed nonperfusing cardiac rhythm in a controlled environment such as the cardiac catheterization laboratory. Coughing episodically increases the intrathoracic pressure and can generate systemic blood pressures higher than those usually generated by conventional chest compressions,[23,24] allowing patients to maintain consciousness[23–26] for a brief arrhythmic interval (up to 92 seconds documented in humans).[25]

“Cough” CPR has been reported exclusively in awake, monitored patients (predominantly in the cardiac catheterization laboratory) when arrhythmic cardiac arrest can be anticipated, the patient remains conscious and can be instructed before and coached during the event, and cardiac activity can be promptly restored.[23–33] However, not all victims are able to produce hemodynamically effective coughs.[27]

“Cough” CPR is not useful for unresponsive victims and should not be taught to lay rescuers. “Cough” CPR may be considered in settings such as the cardiac catheterization laboratory for conscious, supine, and monitored patients if the patient can be instructed and coached to cough forcefully every 1 to 3 seconds during the initial seconds of an arrhythmic cardiac arrest. It should not delay definitive treatment (Class IIb, LOE C).

Prone CPR

When the patient cannot be placed in the supine position, it may be reasonable for rescuers to provide CPR with the patient in the prone position, particularly in hospitalized patients with an advanced airway in place (Class IIb, LOE C).[34–37]

Precordial Thump

This section is new to the 2010 Guidelines and is based on the conclusions reached by the 2010 ILCOR evidence evaluation process.[38]

A precordial thump has been reported to convert ventricular tachyarrhythmias in 1 study with concurrent controls,[39] single-patient case reports, and small case series.[40–44] However, 2 larger case series found that the precordial thump was ineffective in 79 (98.8%) of 80 cases[45] and in 153 (98.7%) of 155 cases of malignant ventricular arrhythmias.[46] Case reports and case series[47–49] have documented complications associated with precordial thump including sternal fracture, osteomyelitis, stroke, and triggering of malignant arrhythmias in adults and children.

The precordial thump should not be used for unwitnessed out-of-hospital cardiac arrest (Class III, LOE C). The precordial thump may be considered for patients with witnessed, monitored, unstable ventricular tachycardia including pulse-less VT if a defibrillator is not immediately ready for use (Class IIb, LOE C), but it should not delay CPR and shock delivery. There is insufficient evidence to recommend for or against the use of the precordial thump for witnessed onset of asystole.

Percussion Pacing

Percussion (eg, fist) pacing refers to the use of regular, rhythmic and forceful percussion of the chest with the rescuer’s fist in an attempt to pace the myocardium. There is little evidence supporting fist or percussion pacing in cardiac arrest based on 6 single-patient case reports[50–55] and a moderate-sized case series.[56] There is insufficient evidence to recommend percussion pacing during typical attempted resuscitation from cardiac arrest.

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CPR Devices

Devices to Assist Ventilation

Automatic and Mechanical Transport Ventilators

Automatic Transport Ventilators: There are very few studies evaluating the use of automatic transport ventilators (ATVs) during attempted resuscitation in patients with endotracheal intubation. During prolonged resuscitation efforts, the use of an ATV (pneumatically powered and time- or pressure-cycled) may provide ventilation and oxygenation similar to that possible with the use of a manual resuscitation bag, while allowing the Emergency Medical Services (EMS) team to perform other tasks (Class IIb, LOE C[57,58]). Disadvantages of ATVs include the need for an oxygen source and a power source. Thus, providers should always have a bag-mask device available for manual backup. For additional information regarding support of airway and ventilation in the adult, see ACLS Part 8.1 in these Guidelines.

Manually Triggered, Oxygen-Powered, Flow-Limited Resuscitators: In a study of 104 anesthetized nonarrest patients without an advanced airway in place (ie, no endotracheal tube; patients were ventilated through a mask), patients ventilated by firefighters with manually triggered, oxygen-powered, flow-limited resuscitators had less gastric inflation than those ventilated with a bag-mask device.[59] Manually triggered, oxygen-powered, flow-limited resuscitators may be considered for the management of patients who do not have an advanced airway in place and for whom a mask is being used for ventilation during CPR (Class IIb, LOE C). Rescuers should avoid using the automatic mode of the oxygen-powered, flow-limited resuscitator during CPR because it may generate high positive end-expiratory pressure (PEEP) that may impede venous return during chest compressions and compromise forward blood flow (Class III, LOE C[60]).

Devices to Support Circulation

Active Compression-Decompression CPR—Active compression-decompression CPR (ACD-CPR) is performed with a device that includes a suction cup to actively lift the anterior chest during decompression. The application of external negative suction during the decompression phase of CPR creates negative intrathoracic pressure and thus potentially enhances venous return to the heart. When used, the device is positioned at midsternum on the chest.

Results from the use of ACD-CPR have been mixed. In several studies[61–66] ACD-CPR improved ROSC and short-term survival compared with conventional CPR. Of these studies, 3 showed improvement in neurologically intact survival.[61,64,65] In contrast, 1 Cochrane meta-analysis of 10 studies involving both in-hospital arrest (826 patients) and out-of-hospital arrest (4162 patients)[67] and several other controlled trials[68–74] comparing ACD-CPR to conventional CPR showed no difference in ROSC or survival. The meta-analysis[67] did not find any increase in ACD-CPR–related complications.

There is insufficient evidence to recommend for or against the routine use of ACD-CPR. ACD-CPR may be considered for use when providers are adequately trained and monitored (Class IIb, LOE B).

Phased Thoracic-Abdominal Compression-Decompression CPR With a Handheld Device—Phased thoracic-abdominal compression-decompression CPR (PTACD-CPR) combines the concepts of IAC-CPR and ACD-CPR. A handheld device alternates chest compression and abdominal decompression with chest decompression and abdominal compression. Evidence from 1 prospective randomized clinical study of adults in cardiac arrest[75] demonstrated no improvement in survival to hospital discharge with use of PTACD-CPR during out-of-hospital cardiac arrest. There is insufficient evidence to support or refute the use of PTACD-CPR for the treatment of cardiac arrest.

Impedance Threshold Device—The impedance threshold device (ITD) is a pressure-sensitive valve that is attached to an endotracheal tube, supraglottic airway, or face mask. The ITD limits air entry into the lungs during the decompression phase of CPR, creating negative intrathoracic pressure and improving venous return to the heart and cardiac output during CPR. It does so without impeding positive pressure ventilation or passive exhalation.

Originally, the ITD was used with a cuffed endotracheal tube during bag-tube ventilation and ACD-CPR.[76–78] The ITD and ACD-CPR devices are thought to act synergistically to enhance venous return. During ACD-CPR with or without the ITD, 1 randomized study[76] found no difference in survival, whereas another randomized study[79] found that the addition of an ITD improved short-term survival (24-hour survival and survival to ICU admission).

The ITD also has been used during conventional CPR with an endotracheal tube or with a face mask, if a tight seal is maintained.[77,80,81] During conventional CPR with and without the ITD, 1 randomized trial[80] reported no difference in overall survival; however, 1 prospective cohort study[82] reported improved survival to emergency department (ED) admission with the use of the ITD. One meta-analysis of pooled data from both conventional CPR and ACD-CPR randomized trials[83] demonstrated improved ROSC and short-term survival associated with the use of an ITD in the management of adult out-of-hospital cardiac arrest patients but no significant improvement in either survival to hospital discharge or neurologically intact survival to discharge.

Three cohort studies with historic controls that implemented 2005 Guidelines plus ITD demonstrated improved survival to hospital discharge for out-of-hospital cardiac arrest.[84–86] It was not possible to determine the relative contribution of the ITD to the improved outcome. The use of the ITD may be considered by trained personnel as a CPR adjunct in adult cardiac arrest (Class IIb, LOE B).

Mechanical Piston Devices—A mechanical piston device consists of a compressed gas- or electric-powered plunger mounted on a backboard; it is used to depress the sternum. Some incorporate a suction cup in the piston device while others do not. In 3 studies[87– 89] the use of a mechanical piston device for CPR improved end-tidal CO_2 and mean arterial pressure during adult cardiac arrest resuscitation. However, compared with manual CPR, no improvement in short- and long-term survival in adult patients was demonstrated.[87,90] Initiation and removal of the mechanical piston device were noted to increase interruptions in CPR.[91]

The Lund University Cardiac Arrest System (LUCAS) is a gas- (oxygen or air) or electric-powered piston device that produces a consistent chest compression rate and depth. It incorporates a suction cup attached to the sternum that returns the sternum to the starting position. There are no randomized control trials comparing the device with conventional CPR in human cardiac arrests. One case series with concurrent controls[92] showed no benefit over conventional CPR for out-of-hospital witnessed cardiac arrest. Additional case series have reported variable success with the device.[93–98] One feasibility study reported successful deployment during diagnostic and interventional procedures.[99]

There is insufficient evidence to support or refute the routine use of mechanical piston devices in the treatment of cardiac arrest. Mechanical piston devices may be considered for use by properly trained personnel in specific settings for the treatment of adult cardiac arrest

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in circumstances (eg, during diagnostic and interventional procedures) that make manual resuscitation difficult (Class IIb, LOE C). Rescuers should attempt to limit substantial interruptions in CPR during deployment. The device should be programmed to deliver high-quality CPR, ensuring an adequate compression depth of at least 2 inches (5 cm)—this may require conversion from a percent of chest depth, a rate of at least 100 compressions per minute, and a compression duration of approximately 50% of the cycle length.

Load-Distributing Band CPR or Vest CPR—The load-distributing band (LDB) is a circumferential chest compression device composed of a pneumatically or electrically actuated constricting band and backboard. Case series have demonstrated improved hemodynamics,[100] ROSC,[101,102] and survival to hospital discharge with use of the LDB for cardiac arrest.[102] In a study using concurrent controls,[103] the use of LDB-CPR was associated with lower odds of 30-day survival (odds ratio 0.4). One multicenter prospective randomized controlled trial[104,104A] comparing LDB-CPR (Auto-pulse device) to manual CPR for out-of-hospital cardiac arrest demonstrated no improvement in 4-hour survival and worse neurologic outcome when the device was used. These results raised concerns about possible harm with use of this device. Further studies are required to determine whether site-specific factors[105] and experience with deployment of the device[106] could influence its efficacy.

The LDB may be considered for use by properly trained personnel in specific settings for the treatment of cardiac arrest (Class IIb, LOE B). However, there is insufficient evidence to support the routine use of the LDB in the treatment of cardiac arrest.

Extracorporeal Techniques and Invasive Perfusion Devices

Extracorporeal CPR—For the purpose of these Guidelines, extracorporeal membrane oxygenation (ECMO) and cardiopulmonary bypass are considered together as different forms of extracorporeal CPR (ECPR; an alternative term may be extracorporeal life support or ECLS) when either is used for resuscitation for cardiac arrest. Both are sophisticated techniques for circulating blood outside the body with or without extracorporeal oxygenation, with the goal of supporting the body's circulation in the absence of an adequately functioning cardiac pump. The initiation of ECPR and the management of a patient on ECPR require highly trained personnel and specialized equipment.

Although there are no data from randomized studies to support the routine use of ECPR, in case series and observational studies the use of ECPR for in-hospital[107,108] and out-of-hospital[109–111] cardiac arrest has been associated with improved survival when compared with conventional CPR in patients <75 years old with potentially correctable conditions. However, supportive studies consisted of small numbers of patients, and some had unbalanced comparison groups with respect to age, witnessed arrest, bystander CPR, and the quality of conventional CPR.

There are no randomized studies that compare ECPR with conventional CPR for patients in cardiac arrest. However, data from several case series have demonstrated the feasibility and safety of ECPR in highly specialized centers.[108,110,111] Observational studies of adults in both the in-hospital[107] and out-of-hospital[109] settings have demonstrated an association between ECPR use and improved survival when compared with conventional CPR in patients with potentially correctable conditions. These studies had small numbers of patients, and some had unbalanced comparison groups with respect to age, witness status, bystander CPR, and the quality of conventional CPR. Please refer to the Pediatrics section for discussion and specific recommendations related to the pediatric population (See Part 14: "Pediatric Advanced Life Support").

There is insufficient evidence to recommend the routine use of ECPR for patients in cardiac arrest. However, in settings where ECPR is readily available, it may be considered when the time without blood flow is brief and the condition leading to the cardiac arrest is reversible (eg, accidental hypothermia drug intoxication) or amenable to heart transplantation (eg, myocarditis) or revascularization (eg, acute myocardial infarction) (Class IIb, LOE C).

Summary

A variety of CPR techniques and devices may improve hemodynamics or short-term survival when used by well-trained providers in selected patients. All of these techniques and devices have the potential to delay chest compressions and defibrillation. In order to prevent delays and maximize efficiency, initial training, ongoing monitoring, and retraining programs should be offered to providers on a frequent and ongoing basis. To date, no adjunct has consistently been shown to be superior to standard conventional (manual) CPR for out-of-hospital basic life support, and no device other than a defibrillator has consistently improved long-term survival from out-of-hospital cardiac arrest.

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Disclosures

Guidelines Part 7: CPR Techniques and Devices: Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Ownership Interest	Consultant/Advisory Board	Other
Diana M. Cave	Legacy Health System, Emanuel Hospital, Emergency Services–RN, MSN; Portland Com. College–Institute for Health Prof.-Faculty/Instructor	None	None	None	None	None	None
Raul Gazmuri	North Chicago VA Medical Center–Section Chief, Critical Care and Professor of Medicine	† Volume-Controlled Manual Ventilation during Resuscitation from Cardiac Arrest. Funded by Dessinier Corporation. Funds come to my institution (Rosalind Franklin UniversityRFU) Vitamin-C Preserves Myocardial Distensibility during Resuscitation from CA. Funded by Maribor University, Slovenia. Funds come to my institution (RFU)	None	None	† Patent titled "Facilitation of Resuscitation from Cardiac Arrest by Erythropoietin" (pending)	None	None
Charles W. Otto	University of Arizona–Professor	None	None	None	None	None	None
Vinay M. Nadkarni	University of Pennsylvania/The Children's Hospital of Philadelphia–Attending Physician,	None	None	None	None	None	* Voluntary (Unpaid) member of Data Safety Monitoring Committee for

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Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Ownership Interest	Consultant/Advisory Board	Other
	Departement of Anesthesia, Critical Care and Pediatrics						Automated CPR device trial
Adam Cheng	British Columbia Children's Hospital: University Affiliated–Director, Pediatric Simulation Program	†American Heart Association RFP - educational grant. Money comes to my institution, and is distributed to our group of collaborative pediatric hospitals	None	None	None	None	None
Steven C. Brooks	University of Toronto–Clinician-Scientist	†PI-1. Univ. of Toronto Faculty of Medicine New Staff Grant. 01/07/2009–01/07/2010 A pilot study to explore missed opportunities for public access defibrillation in OHCA and to determine the potential impact of emergency medical dispatchers. Role: PI $10,000 unrestricted grant administered through the research institute 2. University of Toronto Connaught New Staff Matching Grant 2009–2010. 04/05/2009–03/05/2011 Development of Centres of Excellence to Improve Outcomes after OHCAt: A Pilot Study. Role: PI $23,700 unrestricted grant administered through the research institute 3. Ontario Ministry of Health and Long Term Care and the Sunnybrook Medical Services Alternative Funding Plan Association. 04/22/2009–04/21/2010 2008–2009 Alternative Funding Plan Phase III Innovation Fund Project Funding. Project: "Inventing the Future of Post Cardiac Arrest Care: Collaborative Development of Standardized Patient Care Pathways at Sunnybrook Health Sciences Centre." Role: PI $100,000 unrestricted grant administered through the research institute Co-Investigator 1. National Institutes of Health Slutsky AS (PI) 01/09/2004–01/09/2009 From Bench to Bedside to Curbside. Clinical Research Consortium to improve Resuscitation. Role: Co-Investigator $2, 454, 201 US 2. Canadian Institute of Health Research Slutsky AS (PI) 01/04/2005–01/10/2010 Epistry component of the Resuscitation Outcomes Consortium. Role: Co-Investigator $500,001 3. Laerdal Foundation for Acute Medicine Morrison LJ (PI) 01/12/2007–01/12/2010 Centre Grant Program for knowledge translation projects in post resuscitation care. Role: Co-Investigator $150,000 4. Heart and Stroke Foundation of Canada. Morrison LJ & Dorian P (Co-PI's) 01/12/2007–01/12/2009 Operating Grant in the Area of Resuscitation and Knowledge Transfer for the Strategies in Post-Arrest Care (SPARC) project. Role: Co-Investigator $200,000	None	None	None	None	None
Mohamud Daya	Oregon Health & Science University: Attending Physician– Associate Professor of Emergency Medicine	†PI Resuscitation Outcomes Consoritum - Portland Site, NHLBI, grant is awarded directly to the insitution (OHSU)	None	*Lectures at local, regional and national meetings, income is directly to me, last lectures CPR update at the Timberline EMS conference, there was no honorarium but conference paid for my lodging Stroke Update in Corvallis at Samaritan Health, Honorarium fee was 500 dollars Advanced 12 lead ECG diagnostic algoritms, Lecutre for Philips Healthcare at EMS today, honoarium for 2 lectures was 1000 dollars	*Stock held in the following health care companies; Johnson and Johnson - 250 shares Amgen - 100 shares Roche - 100 shares	*Philips Health Care - Consultant on 12 lead ECG diagnostic algorithms and resuscitation products, no reimbursement for this activity	†I am an EMS medical director for 2 fire departments and one 911 agency, this is a private contract and the money comes directly to me, this is independent of my employment at OHSU which is at an 80% FTE level, my EMS activities are 20% FTE
Robert M. Sutton	The Children's Hospital of Philadelphia–Critical Care Attending	*Unrestricted Research Grant Support through a Center of Excellence Grant from the Laerdal Found	None	None	None	None	
Richard Branson	University of Cincinnati-Associate Professor	None	†SeQual. Sponsor of laboratory study of the use of oxygen concentrators in conjunction with mechanical ventilators for military and mass casualty scenarios. $40,000. All monies are paid to the Univ. I have no financial interest in the company and do not receive any personal income	†Cardinal - makers of ICU and home care ventialtors. I am paid directly for speaking. Newport Medical makers of ICU and home care ventilators. I am paid directly for speaking. *IKARIA - manufactures and distributes inhaled nitric oxide. I am paid directly	None	*Bayer Pharmaceuticals. Treatment of ventilator associated pneumonia	*KIngs Daughters Hospital Ashalnd KY. Paid directly to me
Mary Fran Hazinski	Vanderbilt University School of Nursing—Professor; American Heart Association–Senior Science Editor †Significant AHA compensation for my editing responsibilities-writing and editing of the 2010 AHA Guidelines for CPR and ECC	None	None	None	None	None	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

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