Epidemiology, Pathology, Assessment, Clinical Profile, Management, and Preventative
Measures of Commotio Cordis

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COMMOTIO CORDIS

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Commotio Cordis (CC) is a phenomenon in which a sudden, blunt impact to the chest results in sudden death in the absence of heart disease or cardiac damage (Link, 2012). The true prevalence of CC is unknown due to the under-recognition of the condition among the medical and lay communities. It is a devastating event in which the epidemiology primarily affects young, male athletes. The mechanism of sudden death appears to be multi-factorial and requires the confluence of several determinants, which result in ventricular fibrillation (VF). Cardiopulmonary resuscitation (CPR) with rapid defibrillation is the accepted life-saving treatment for VF. Having an automated external defibrillator (AED) readily available may improve outcome. Safety baseballs and chest protectors are one area of focus in the primary prevention of CC. Secondary preventative measures include providing access to AEDs in athletic settings and providing education regarding their use. Increasing public awareness of commotio cordis as an important cause of sudden death in athletes may ultimately reduce this increasingly recognized tragic event.
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*Keywords*: commotio cordis, sudden death, athletes, cardiac trauma, chest impact, ventricular fibrillation
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Epidemiology, Pathology, Assessment, Clinical Profile, Management, and Preventative Measures of Commotio Cordis

Purpose

The sudden death of a healthy child is tragic. Nowhere is this truer than when an athlete gets struck down while pursuing healthy activities. Something as simple as being hit in the chest can cause instantaneous death. Commotio Cordis (CC) is defined as a non-penetrating low impact trauma to the chest wall that results in ventricular fibrillation (VF) causing sudden death (Perron, Brady, & Erling, 2001). It is a cardiac concussion phenomenon which occurs in the absence of heart disease or injury to the structures surrounding the heart. The absence of chest trauma or cardiac bruising distinguishes commotio cordis from contusio cordis, the latter meaning cardiac contusion. Commotio cordis has only recently received attention, although incidences may be traced back to the late 1800s. Throughout most of the 20th century, cases have only been sporadically reported; thus, the true prevalence of CC is unknown. It is thought that the increase in the number of cases reported is not due to the increase in CC events, but rather due to increased public awareness, especially within sports communities.

Since the initiation of the United States Commotio Cordis Registry (USCCR) in 1996, over 200 cases have been confirmed, with the majority constituting young athletes. Among the cases reported and analyzed, two prevailing themes occur: 1) the predisposition for the youth with a mean age of 15±9 years and 2) a higher prevalence among males (Maron & Estes III, 2010). Pliable chest walls and narrow anteroposterior (AP) diameter of the chest is believed to place young athletes at increase risk. Review of the literature suggests most cases have occurred during recreational or competitive sports, with the most common being baseball, hockey,
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lacrosse, and softball (Zangwill & Strasburger, 2004). Nearly all events of commotio cordis were caused by baseball strikes directly over the cardiac silhouette. Pitchers, catchers, and batters are known to have the highest incidences of chest wall blows (Link, 2012).

While commotio cordis is most frequently encountered in the setting of athletic events, some instances have also resulted during activities unrelated to sports. Interestingly, it has been the cause of death in homicides, motor vehicle accidents, falls, and in events of normal daily living in which bodily contact with instruments resulted in sudden death due to blunt chest trauma.

It is postulated that there are three major determinants in the mechanism of sudden death in commotio cordis. Lateef (2000) found that they are the location of impact, the timing of impact, and the force of impact. Link and colleagues (1998) discovered, using a swine model, that ventricular fibrillation could be reproduced 9 out of 10 times if chest wall impact occurred between 10 and 30 ms prior to the peak of the T wave in the cardiac electrical cycle. Based on these findings, ventricular fibrillation initiated by chest wall impact is likely the cause of death in CC. Recently, another possibly critically important determinant has surfaced which may explain the uncommon occurrence of commotio cordis. Alsheikh-Ali, Madias, Supran, and Link (2010), have hypothesized that individual susceptibility may be a contributing factor for the induction of VF following a chest blow. With the above knowledge, prompt defibrillation with an automatic external defibrillator (AED) may prevent sudden death in the presence of commotio cordis.

The purpose of this paper is to review and summarize the most current evidence for the (a) epidemiology (b) pathology (c) assessment (d) clinical profile (e) management and (f) possible preventative measures of commotio cordis. The population of interest will be limited to the clinical profile of CC in relation to the young athlete.
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Data Sources

A search of the literature was conducted using the key words of “commotio cordis,” “sudden death,” “athletes,” “cardiac trauma,” “chest impact,” and “ventricular fibrillation.” CINAHL, Pubmed, MEDLINEplus, and Web of Science databases were used to locate full text articles that were printed in English and published in peer reviewed journals since 1998. Thirty articles were identified and reviewed, 21 articles were selected for inclusion based on content and relevance. The 21 articles were then analyzed and organized into the following categories: epidemiology and pathology (9 articles), assessment and clinical profile (7 articles), and management and preventative measures (5 articles). Prevention and safety tips were also incorporated from the American Academy of Pediatrics (AAP) and the National Operating Committee on Standards for Athletic Equipment (NOCSAE) websites. Based on this organizational framework, the information was then synthesized in the review of literature.

Theoretical Framework

The Neuman’s Systems Model provides the conceptual framework that guides this literature analysis. The model was developed by Betty Neuman in 1972 and focuses on the human need for dynamic balance. One of the basic assumptions of the model is the concept of “prevention as intervention” (McEwen & Wills, 2011). The model is aimed at maintaining an optimum level of functioning, i.e. health promotion and disease prevention, which is the core of nursing practice. Understanding how the model views the nursing process gives insight into preventative strategies.

In the Neuman’s Systems Model, primary prevention consists of identification and reduction of possible risk factors. Examples aimed at the primary level include: increasing awareness through public education; modifying lifestyle risks; improving protective sports
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equipment; and training of athletes, parents, and coaches. Secondary prevention relates to intervention and treatment. Prompt recognition, early activation of advanced life-support measures, and immediate access to AEDs may be life-saving secondary interventions in commotio cordis. Defining intervention through prevention in the Neuman Model provides a theoretical framework to address the management and possible preventative measures of CC.

Literature Review

Epidemiology and Pathology

Commotio cordis is derived from Latin, meaning “disturbance of the heart” (Madias, Maron, Weinstock, Estes III, & Link, 2007). It refers to the induction of VF or instantaneous sudden death produced by a blunt, non-penetrating chest wall blow. Nesbitt, Cooper, and Kohl (2001) propose the following pathology of commotio cordis: “mechanical stimulation of the heart by non-penetrating, impulse-like impact to the precordium that, through intrinsic cardiac mechanisms, gives rise to disturbances of cardiac rhythm of varying type, duration, and severity, including sudden cardiac death, in the absence of structural damage that would explain any observed effects” (p.1196).

The term commotio cordis has been applied to various lethal and non-lethal forms of cardiovascular disorders as early as 1857. Case reports from the 1870s include accounts of immediate deaths following mechanical impacts to the chest (Nesbitt et al., 2007). By the 20th century, commotio cordis-related deaths prompted experiments conducted by Georg Schломка, who was first to provide electrocardiographic evidence of sudden death following a chest impact. Schломка was also the first to utilize the term commotio cordis in an article title (Geddes & Roeder, 2005).
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Commotio cordis has now been recognized as a major cause of death in young athletes in the United States, after hypertrophic cardiomyopathy and congenital coronary-artery anomalies (Maron & Estes III, 2010). Once considered a rare occurrence, it is now apparent that these events have been previously under-reported and under-recognized. The combination of increased public interest and probable legal implications has contributed to the increased awareness and reporting of this condition.

Since the formation of the USCCR in 1996, 224 cases of commotio cordis have been documented. Most of these reported cases have been within the setting of youth sporting activities. Of the cases accrued, 26% of victims were ten-years-old or younger and only 9% of cases were age 25 or older. Fifty percent of those events occurred during organized, amateur sports such as baseball, softball, ice hockey, football, or lacrosse. Another 25% of events occurred in recreational sports that took place at home, on the playground, or at family gatherings (Maron & Estes III, 2010). Generally, victims were struck by a blunt object, such as a baseball, hockey puck, or lacrosse ball. Velocities of pitched, batted, or thrown balls were estimated to be between 48-80km/h or 30-50 mph (Madias et al., 2007). In some instances, athletes were wearing commercially standard chest wall protectors to provide coverage, however, the device failed to cover the precordium at the time of impact. Most of the fatal chest wall blows occurred to the left of the sternum directly over the cardiac silhouette. Sudden cardiac death is virtually instantaneous, thus requiring immediate intervention to achieve positive outcomes.

The predisposition for CC in young athletes is likely due to the physical characteristics of a young person’s thorax. The narrow AP diameter and increased compliance of the chest wall are thought to contribute to the arrhythmic consequence of a precordial impact. The more fully
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developed adult chest, thicker and less compliant, may explain why adults who participate in high impact sports account for a low percentage of commotio cordis related events.

The mechanism of CC was poorly understood prior to 1998. Experiments by Schlomka using animal studies reproduced electrocardiogram (ECG) changes, most notably VF. However, most blows utilized high velocity or high-energy objects which may have resulted in sudden death from cardiac contusion, rather than commotio cordis (Link, 2003).

Subsequent studies by Link and colleagues (1998) attempted to mimic the clinical profile of CC using anesthetized juvenile swine. In their model, the swine were placed in a sling and were struck by a propelled baseball at velocities similar to youth baseball. The impacts were directly placed over the cardiac silhouette and were timed to a vulnerable period within the cardiac cycle. The most significant finding found CC to be primarily due to the initiation of VF following a blow to the chest wall. Evidence also suggested the underlying mechanism of impact-induced VF was multi-factorial and required the convergence of several determinants: timing, location, and force of impact.

The timing of impact to the cardiac cycle was found to be the most important variable. Impacts occurring at 0-40 milliseconds (ms) in the narrow window prior to the peak of the T wave caused VF reliably, with the most lethal impact occurring within the 10-30ms window (Link & Estes III, 2007). Interestingly, when chest blows occurred outside of this narrow vulnerable period in the cardiac cycle, VF was not induced. Although transient in nature, dysrhythmias such as heart blocks, ST-segment elevation, and premature ventricular contractions (PVCs) were found to emerge (Link, 2003). The importance of impact location was also observed. The induction of VF occurred most frequently when a blow was directed over or near the center of the left chest wall. According to Link (2012), strikes that did not occur over the
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cardiac silhouette did not result in ventricular fibrillation. Finally, the force of impact is also critical to the mechanism of CC. The threshold velocity for VF induction in the models was 25-30mph with an increase in incidence as the impact of force increased. This observation is consistent with the spectrum of CC that occurs most often in baseball, as these balls are dense and traveling at velocities ranging from 30-50mph (Madias et al., 2007).

Recent literature has identified other possible variables involved in the induction of ventricular fibrillation in commotio cordis. There is some evidence to suggest that there is an intrinsic susceptibility for CC, similar to prolonged QT syndrome. In a retrospective analysis of 139 juvenile swine, a wide variability in susceptibility to VF was discovered. Animal studies suggest that abnormalities in cardiac depolarization and repolarization may contribute to this unique susceptibility (Alsheikh-Ali et al., 2010). Another hypothesis, proposed by Link (2012), suggests that males may be at more risk than females. The author suggests that males may possess less repolarization reserve or ion channels in the cardiac cycle that lead to increased left ventricular pressures, which may produce VF in the event of CC. The hypothesis that victims of commotio cordis are predominantly male needs empirical validation through further research.

Assessment and Clinical Profile

Autopsies in victims of commotio cordis were notable for lack of significant cardiac or thoracic abnormalities (Link, 2003). Recognizing that victims of CC have no prior history of heart disease or structural abnormalities is important when considering the evolution of this acute condition.

Other causes must also be considered, including syncope and cardiac contusion. Syncope refers to a transient loss of consciousness and may mimic commotio cordis; however, syncope is not usually associated with a strike to the chest wall and in most cases a prodrome of dizziness
COMMOTIO CORDIS occurs. Cardiac contusions (AKA contusion cordis), may be distinguished clinically from commotio cordis due to the direct chest injuries associated with myocardial contusion. Contusio cordis causes structural damage with little change in level of consciousness or blood pressure and infrequently causes ventricular arrhythmias (Lateef, 2000). Stress echocardiography or MRI is useful in diagnosing cardiac contusion due to the associated ventricular wall motion abnormalities, as well as thoracic skeletal injuries (Zangwill & Strasburger, 2004).

While most victims of commotio cordis collapse after an immediate blow to the chest wall, there are isolated cases of victims collapsing briefly thereafter (Perron, Brady, & Erling, 2001). Sudden death may be instantaneous or preceded by syncope. Lateef (2000) characterizes CC by an immediate clinical presentation of loss of consciousness, hypotension and ventricular arrhythmias. These transient symptoms may suggest the possibility of an initial rhythm of ventricular tachycardia prior to the fatal arrhythmia of ventricular fibrillation.

Diagnostic findings in commotio cordis are typically normal. Cardiac enzymes including troponin levels are within the reference range without signs of infarction (Confalone, 2005). Echocardiography, as well as immediate coronary angiography, usually displays a normal functioning heart without coronary artery abnormalities (Link, 2003). As previously mentioned, MRI or echocardiography may rule in other conditions that may mimic commotio cordis.

**Management and Preventative Measures**

Survival rates of CC, based on the cases reported in the USCCR, now approaches 35%, compared to the previous 15% reported in the 1990s decade (Maron & Estes III, 2010). Although survival rates have increased, it is still unacceptably low. The likelihood of poor outcome results from failure to effectively initiate timely treatment. Survival depends on the early recognition of CC and instituting immediate resuscitative measures. Resuscitative
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measures performed within 3 minutes of the event, resulted in survival rates approaching 25%. In cases that were delayed in basic life support for more than 3 minutes, survival rates were a mere 3% (Salib, Cyran, Cilley, Maron, & Thomas, 2005). The American Heart Association cardiopulmonary guidelines recommend immediate CPR and rapid defibrillation for ventricular fibrillation. The sooner the defibrillation attempt the more likely the positive outcome.

Understanding the known pathophysiology of commotio cordis, most often resulting in ventricular fibrillation, confirms the critical to use an AED in this setting. AEDs have been shown to treat VF in commotio cordis victims and the need for these accessible devices is essential. In a study by Link (2012), all episodes of VF induced on animal models were successfully terminated with the use of the AED. If defibrillation occurred, within a two minute period, the majority of cases had a spontaneous return of circulation. In 2001, use of the automatic external defibrillator was revised to administer appropriate voltages to children under the age of 8 and is currently approved for use in individuals older than one year (Valani, Mikrogianakis, & Goldman, 2004).

The application of a sharp blow to the sternum using one’s fist, for the purpose of reviving a victim of cardiac arrest, is known as the precordial thump (PT). However, this practice remains controversial. The actual mechanism of effectiveness continues to strike debate and some argue that when applied, the force may actually worsen an arrhythmia and delay application of an AED, which may be detrimental. Miller and Bhakta (2007) found the success rate of PT to be low and variable, ranging from 1-60%, when treating cardiac arrhythmias but they suggest at least a single attempt if warranted. Current guidelines by the AHA suggest PT may be considered in a witnessed, monitored, unstable ventricular tachycardia if an AED is not readily available. However, the use of the PT should never delay CPR or shock delivery by a
COMMOTIO CORDIS defibrillator (AHA, 2010). While the mechanism and use of the precordial thump remains unclear, this easily applied, readily available intervention may be life-saving in some situations and its use should not be discounted.

Primary prevention measures include increasing public awareness, implementing a plan of action in settings where commotio cordis may occur, and the use of protective sports equipment. Given the direct correlation between the hardness of a sports ball and the likelihood of VF following a sudden impact. Improving the design of balls used in sporting events, such as a baseball made entirely of rubber, instead of the dense, hard core of cork and twine could also prevent CC (Valani et al., 2004). Air filled balls may significantly reduce the risk of cardiac death due to their propensity to collapse and possibly absorb some of the force of the impact. In an experimental model, soft safety baseballs triggered VF in 11% of chest impacts in contrast to 69% of impacts with the standard baseball (Madias et al., 2007).

Chest protectors and vests are also ways to reduce the likelihood of blunt chest trauma resulting in CC. However, it has been found that chest protectors worn by some athletes did not provide absolute protection against CC. In a study by Doerer, Haas, Estes III, Link, and Maron (2007), a significant proportion (40%) of sudden deaths reported in young athletes occurred despite wearing a commercially available chest barrier. In an experimental study conducted by Weinstock et al. (2006), VF was elicited in animal subjects with and without the use of commercially available chest protectors. None of the baseball or lacrosse chest wall protectors tested decreased the occurrence of VF when evoked. While chest protectors have been advertised and advocated as providing protection against trauma to athletes, their use may primarily protect against soft tissue and bone injury, but not against the fatal blows of commotio
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cordis. Currently, efforts are underway toward improving the design and composition of chest protectors in enhancing the protection from CC related blows.

Improved coaching techniques may reduce the risk of CC. Teaching young batters in baseball to turn away from erratic pitches and coaching defensive players in hockey and lacrosse to avoid using their chest when blocking the goal are also efforts aimed at primary prevention.

A strategy of incorporating more AEDs in sporting venues and settings where commotio cordis may occur is likely to result in a higher survival rate of young athletes. Considering the mechanism of sudden death caused by VF in commotio cordis, AEDs have significant life-saving capabilities. Clinical proof of the efficacy of AEDs in life-saving situations can be proffered to justify the need for widespread purchases of these devices and training of personnel in their use (Salib, Cyran, Cilley, Maron, & Thomas, 2005). Providing wider access to these devices and disseminating them in sporting related events taking place in high schools, colleges, and park districts is crucial.

Discussion

Significance to Nursing

Nurse practitioners (NP’s) believe in promoting health and preventing illness. The ultimate goal of health promotion is focusing on the levels of prevention. Primary and secondary prevention can lead to improved outcomes for athletes who suffer from cases of commotio cordis. Primary prevention includes educating the public and medical communities. Encounters with patients and their families provide an opportunity for education in the clinical setting. Nurse practitioners should identify high risk athletes during sports physicals. NP’s can also be instrumental in developing strategies for community-based education, for groups such as athletes, coaches, and first responders. Working in partnership with the communities they serve,
nurse practitioners can play a pivotal role in promoting awareness of commotio cordis and its relation to sudden death. Nurse practitioners need to advocate for improving access to AEDs, as these devices have life-saving capabilities for the athletes and spectators alike. Early recognition of symptoms associated with this entity and timely intervention of life support and defibrillation are critical.

**Recommendations for Future Research**

Although not an entirely new phenomenon, commotio cordis has only recently achieved visibility in the medical and lay communities in the last two decades. An understanding of the epidemiology and past experimental models of CC, has led to more recognition of the condition with young athletes who are exposed to the greatest risk. Currently, the survival rate is poor and outcome largely depends on initiation of early resuscitation and defibrillation. Early recognition allows immediate intervention which may be life-saving. Preventative research should focus on improvements in the design and composition of chest barriers. Emphasizing the inadequacy of current chest barriers is fundamental in improving the design of these chest wall protectors. The construction of protectors with novel materials, such as polypropylene beads that are capable of absorbing and dissipating impact energy, is a consideration in new designs protecting against precordial impacts (Weinstock et al., 2006). It is also likely that barriers made from more solid and resistant material would be more effective.

Safety baseballs are another consideration aimed at prevention. The NOCSAE organization proposes the development of specially designed balls in affording greater impact safety. The AAP endorses the use of a “safety” baseball, which is softer than the material found in standard baseballs. The academy also promotes the use of protective athletic equipment to be worn to possibly prevent the traumatic injury associated with CC.
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Finally, further efforts are needed in providing more education to the general public and medical communities. Increasing public awareness of this phenomenon and testing the effectiveness of various methods of public education is essential. For example, public education programs could be examined to identify the most effective methods of distributing public service announcements about CC via the public airways and internet, and by placing written brochures in primary care offices. Continued emphasis on the occurrence of CC during athletic events should focus attention in training allied professionals and sports officials in the management of commotio cordis. The more education provided to emergency personnel and the lay person will increase the odds of prompt intervention and successful resuscitation. All of the above improvements are necessary in enhancing the safety of our young athletes.
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