Available online at www.sciencedirect.com
ScienceDirect
Forensic Science International 172 (2007) 56–62
Forensic Science International
www.elsevier.com/locate/forsciint

A comparison of pulmonary intra-alveolar hemorrhage in cases of sudden infant death due to SIDS in a safe sleep environment or to suffocation

Henry F. Krous [a,b,*], Elisabeth A. Haas [a], Homeyra Masoumi [a], Amy E. Chadwick [a], Christina Stanley [c]

[a] Department of Pathology, Rady Children's Hospital–San Diego, 3020 Children's Way, MC5007, San Diego, CA 92123, USA
[b] Department of Pathology, University of California, San Diego, School of Medicine, La Jolla, CA, USA
[c] Office of the Medical Examiner, County of San Diego, CA, USA

Received 23 May 2006; received in revised form 15 November 2006; accepted 12 December 2006
Available online 12 January 2007

Abstract

The differentiation of SIDS from accidental or inflicted suffocation may be impossible without corroborating findings from the death scene or autopsy or in the absence of a confession from a perpetrator. Pulmonary intra-alveolar hemorrhage (PH) has been proposed as a potential clue to suffocation, but none of the previous studies on this topic have limited SIDS cases to those who were in a safe sleep environment, in which all were found supine and alone on a firm surface with their heads uncovered. Our aims are to: (1) compare PH in SIDS cases found in a safe sleep environment to a control group comprised of infants whose deaths were attributed to accidental or inflicted suffocation and (2) assess the effect of age, CPR, and postmortem interval (PMI), with regard to the severity of PH in this subset of safe-sleeping SIDS cases. We conducted a retrospective study of all postneonatal cases accessioned by the Office of the Medical Examiner in San Diego County, California who died of SIDS or suffocation between 1999 and 2004. A total of 74 cases of sudden infant death caused by SIDS (34 cases as defined above, comprising 8% of the total SIDS cases), accidental suffocation (37), and inflicted suffocation (3) from the San Diego SIDS/SUDC Research Project database were compared using a semiquantitative measure of pulmonary intra-alveolar hemorrhage. The most severe (grade 3 or 4) PH occurred in 35% of deaths attributed to suffocation, but in only 9% of the SIDS cases. Age, duration of CPR attempts and PMI had no effect on the severity of PH in SIDS. Our results indicate that the severity of PH cannot be used independently to differentiate SIDS from suffocation deaths. Each case must be evaluated on its own merits after thorough review of the medical history, circumstances of death, and postmortem findings.

Keywords: Pulmonary hemorrhage; SIDS; Infanticide; Sudden infant death; Suffocation; Oronasal blood; Child protective services

1. Introduction

Sudden infant death syndrome (SIDS) is generally defined as the sudden unexpected death of an infant less than 1 year of age, with onset of the fatal episode apparently occurring during sleep, that remains unexplained after a thorough case investigation, including performance of a complete autopsy and review of the circumstances of death and the clinical history [1]. As such, SIDS remains a diagnosis of exclusion. There are cases, however, in which SIDS cannot be differentiated from accidental or inflicted suffocation by postmortem examination alone when the autopsy findings are minimal, and none are considered pathognomonic for a cause of death. This is particularly true in cases of ''soft'' suffocation when pathologic findings diagnostic of oronasal occlusion or chest compression are not identified at autopsy. Consequently, some SIDS cases have been reclassified as suffocation after re-evaluation of the circumstances of death [2–7]. There are a few cases that are determined either by a confession from the perpetrator or by a convincing demonstration of an unsafe sleep site. Therefore, investigators continue their search for postmortem pathologic findings that may serve

* Corresponding author at: Rady Children's Hospital and Health Center, 3020 Children's Way, MC5007, San Diego, CA 92123, USA. Tel.: +1 858 966 5944; fax: +1 858 966 8087.
E-mail address: hkrous@chsd.org (H.F. Krous).

0379-0738/$ – see front matter © 2006 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.forsciint.2006.12.005

to distinguish SIDS from suffocation. In this regard, oronasal blood (ONB) on infants discovered lifeless and prior to the onset of any cardiopulmonary resuscitation (CPR) has been identified after attempts at inflicted suffocation and has been suggested as a potential postmortem marker for either accidental or inflicted suffocation of infants [8,9].

Pulmonary intra-alveolar hemorrhage (PH) is another finding that has received attention; the existent literature suggests that it cannot be used as an independent diagnostic marker [1,10–13]. There are, however, significant limitations in these previously published studies that confound our understanding of PH in sudden infant death which we have discussed in our earlier investigations [13]. Therefore, in this study, we: (1) compare PH in a subset of SIDS cases from our earlier investigation, who were found supine, alone, and in a safe sleep environment to a control group of infants who died of accidental or inflicted suffocation and (2) assess the effect of age, CPR, and postmortem interval on the severity of PH in cases limited to the SIDS subset only.

2. Materials and methods

The Rady Children's Hospital-San Diego Institutional Review Board approved this study. From all postneonatal infants (29–365 days of age) accessioned by the San Diego County Medical Examiner's Office (ME) into the San Diego SIDS Research Project database between 1991 and 2004, cases were selected whose deaths were attributed to SIDS and who were found in a safe sleep environment (supine, alone and on a firm surface, with head uncovered; heretofore referred to as ''safe-sleeping SIDS'') as well as cases whose deaths were caused by accidental or inflicted suffocation. SIDS cases not meeting the safe sleep environment criteria were excluded, as well as cases for which cause of death was either undetermined or due to other natural diseases, and cases where death was delayed after successful cardiopulmonary resuscitation (CPR).

Case data were selected from the medical history, death scene, and postmortem information in the investigative and autopsy reports and from two standardized data protocols for the death scene investigation and postmortem examination. In 1989, a California statute mandated use of standardized scene investigation and postmortem examination protocols for cases of sudden, unexpected infant death without external evidence of inflicted injuries. Trained, experienced investigators from the ME are charged with collecting this information within 30 h of an infant's death. The data are not complete for every case.

A diagnosis of SIDS was made only when criteria were fulfilled for the general definition recently proposed in 2004 in San Diego [1]. Cases of accidental or inflicted suffocation were diagnosed upon analysis of information obtained from the medical histories, circumstances of death, and postmortem findings. Table 1 delineates the details of these deaths. Pulmonary hemorrhage was never used as a diagnostic criterion to assign the cause of death to either accidental or inflicted suffocation.

A total of 74 cases were included for evaluation in this study: safe-sleeping SIDS, 34 cases; accidental suffocation, 37 cases; and inflicted suffocation, 3 cases. Since the mechanism of death was similar, the 40 cases of accidental and inflicted suffocation were combined into a single control group for comparison with the SIDS cases. These 40 control cases represent every infant whose death was caused by suffocation accessioned by the ME during the period of 1991–2004. Microscopic sections of the lungs were available for evaluation on all of the cases in both groups. As a result of our previous investigation [14], we have data on Child Protective Service (CPS) referrals and their adjudication for cases from 1991 through 2000 only. CPS data for cases beyond the year 2000 are not available because our IRB approval extended only through the year 2000.

The presence of oronasal blood (ONB) exuding from the nose and mouth, which was based on the description of the first person to discover the infant prior to the onset of CPR [9], was compared between the SIDS and suffocation control groups. Any other described secretions, e.g., purge, pink froth, bloody froth, vomitus, or formula, were not considered in this analysis. ONB was not used as an independent criterion to assign a cause of death to suffocation. The postmortem interval (PMI) was defined for this study as the interval from the date and time of pronounced death until the date and time the postmortem examination was begun; as such, it is an underestimate, given that many of these infants had been dead for extended intervals before discovery.

Table 1
Asphyxial deaths, $n = 40$

Mechanisms	Cases (n)
Wedged	13
Oronasal obstruction (e.g. plastic bag)	8
Face down embedded in soft sleep surface	5
Overlaying	10
Found dead beneath sibling or parent	*6*
Co-sleeping on couch with parent	*2*
Found face down next to parent with blood around nose and mouth and on bedsheets	*1*
Sleeping between parents on small inflatable mattress while camping	*1*
Confessed or witnessed homicidal smothering	3
Suspended in ''bouncy seat'' with anterior neck compression	1

The lung sections were generally taken from each lobe of both lungs, although not in every case. The mean numbers of microscopic sections of the lungs for the SIDS and suffocation control cases were 4.6 ± 1 and 4.4 ± 1.4, respectively. The entirety of the tissue in the microscopic sections was scanned by one pathologist (HM) at a magnification of 40× to score the severity of the pulmonary hemorrhage (PH). Intra-observer reproducibility (κ) testing was calculated at 1.00. PH was semiquantitatively assessed in hematoxylin and eosin (H&E) stained sections of formalin-fixed lung using the following grading system: grade 0 = none; 1 = mild (Fig. 1); 2 = moderate and focal; 3 = moderate and multifocal (Fig. 2); 4 = diffuse and severe.

The presence and distribution of intrathoracic petechiae (IP) were recorded from the postmortem records.

3. Data analysis

Safe-sleeping SIDS and suffocation control cases were compared to one another with respect to medical history,

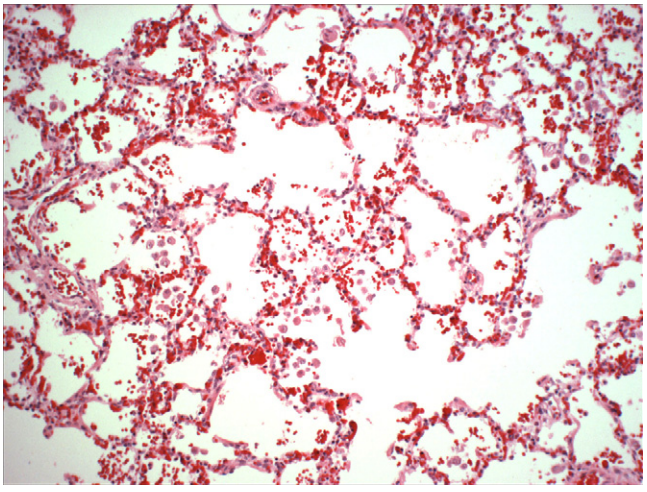

Fig. 1. Grade 1 pulmonary hemorrhage in a 4-month-old male found supine on a large bed with face covered by sleeping sibling's leg. The cause of death was determined to be suffocation. H&E, 100×.