EXHIBIT V

Supplementary Report for the Inquiry into the Convictions of Kathleen Megan Folbigg

Relating to Caleb Folbigg

1. The only abnormal finding for Caleb appears to be the histology of the lungs, "congested and in places show incomplete aeration, in other sections their alveoli contain extravasated red blood cells and a small amount of eosinophilic exudate. These are proteins that pick up the eosin stain and a common finding in post mortem lungs and often seen in samples from children diagnosed with SUDI (Prof. J. A. Morris, personal communication).

2. The source of Caleb's eosinophilic exudate was not investigated. No microbiology examination was carried out on samples from the child. This is important as a variety of infectious agents identified in SIDS/SUDI can elicit inflammatory responses. These include a variety of viruses, bacteria, *Chlamydia trachomatis* [Lundemose *et al.,* 1990], and *Pneumocystis carinii* [Vargas et al., 1999] *Pneumocystis jerovici* (Prof. P.N. Goldwater, personal communication).

3. There was also no assessment of lung immunoglobulins which also found to be raised in SIDS/SUDI [Forsyth *et al.*, 1989].

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13 March 2019

these changes varied simply with loss of sleep. This, however, did affect choice reaction time in which the ability to maintain a constant level of performance over blocks of trials was impaired. Wilkinson found the same effects after deprivation of sleep, provided the task exceeded five minutes; compensation was possible in tasks of up to five minutes' duration.[15] The need to sustain performance for longer than five minutes, which also applied to our study, may have a bearing on the results of Poulton *et al*, who concluded from a study of 30 junior doctors who had lost between three and eight hours' sleep that the doctors could compensate on the basis of tasks of less than five minutes' duration.[5]

Though mood ratings do not have the same objectivity as the cognitive measures, the values obtained here corroborate earlier results in which the same mood schedule was examined in a study of the effects of 24 hours' deprivation of sleep in volunteers.[12] In our study the house officers showed significant deleterious changes in all the mood scales after night duty.

Laboratory evidence of the adverse effects of night duty may nevertheless underestimate their implications for the ward environment and their consequences for the doctor-patient relationship. As in previous studies the length of testing, here a 35 minute session, was necessarily curtailed to encourage cooperation with testing. Even so, many doctors were unwilling to participate. If the test sessions had been longer more complex inaccuracies in performance and cognitive functions may well have been manifested. The raised scores on the confusion-bewilderment scale suggest such a potential.

In conclusion the reduction in cognitive performance combined with the adverse changes in mood show less than desirable conditions for personal wellbeing and the practice of medicine. Superimposed night duty rosters may be a stress adversely affecting the welfare of both the doctor and the patient.

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Lung immunoglobulins in the sudden infant death syndrome

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Abstract

The incidence of the sudden infant death syndrome parallels that of respiratory tract infections in the paediatric community. On the basis that the aetiology of the sudden infant death syndrome may lie in an unusual response to a trivial intercurrent respiratory infection a necropsy study was carried out investigating pulmonary immunoglobulins in 16 victims of the syndrome and a series of infants (controls) who had died of non-pulmonary causes. Compared with the controls victims of the sudden infant death syndrome had grossly raised concentrations of IgG, IgM, and to a less extent IgA in lung lavage samples. In addition, pulmonary interstitial and terminal airway cells expressing these immunoglobulins were identified far more often in victims than controls. The study failed to determine whether the increased immunoglobulin concentrations were a consequence of an unusual response to a trivial infection or an expression of otherwise altered immunological control in the respiratory tract.

Epidemiological evidence and the findings of this study suggest that the respiratory tract is the prime target organ in the sudden infant death syndrome.

Introduction

The sudden infant death syndrome is the main cause of mortality in the first year of life in developed countries. Despite extensive efforts, no unifying concept of pathophysiology can explain most cases.[1] Analysis of epidemiological data shows that the syndrome is more common in colder climates during the winter and that its incidence correlates with respiratory tract infections, particularly rates of admission to hospital for bronchiolitis.[2] A highly significant correlation has been reported between the isolation of respiratory viruses in the general paediatric population and the incidence of the sudden infant death syndrome.[3] Often victims of the syndrome have an upper respiratory tract infection in the week preceding death,[4] some 40-75% of victims having evidence of mild upper respiratory tract infection with various viruses.[5] Hence an unusual response to a common viral pathogen is epidemiologically possible. Analysis of the immunological state of the lung may therefore help to answer whether immunological dysregulation is occurring in the sudden infant death syndrome.

The aim of this study was to measure concentrations of immunoglobulins IgG, IgA, and IgM in lung lavage samples from victims of the sudden infant death syndrome and compare them with values in controls. In addition, the presence of these immunoglobulins in cells within lung sections collected at necropsy were quantified and compared with controls.

Subjects and methods

All previously well infants who die suddenly and unexpectedly (presumptive sudden infant death syndrome) in South Australia come to necropsy at the Adelaide Children's Hospital by direction of the state coroner. We collected lung lavage samples and lung tissue from 16 such cases (mean age of victims 3·8

months, range 1-7). Using the same procedure we also collected lung lavage samples from eight controls (mean age 4·8 months, range 2-10) and lung tissue from four controls (mean age 5·3 months, range 3-9). The controls were previously well children who had died of acute, non-pulmonary causes. They came to necropsy because they had congenital abnormalities or had died as a result of an accident. Accident victims with pulmonary contusion were excluded. In all cases specimens were collected 12 to 24 hours after the presumed time of death. The results of cellular and virological studies have been reported.[6]

Lung lavage fluid immunoglobulin concentrations—Immunoglobulins IgG, IgA, and IgM were measured by a sensitive competitive inhibition enzyme immunoassay.[7] Briefly, polystyrene tubes were used as the solid phase and coated with the appropriate pure immunoglobulin (rabbit antihuman IgG, IgA, or IgM; DAKO, Denmark). The lavage samples were diluted 50% and added to the solid phase together with purified antihuman IgG, IgA, or IgM coupled to horseradish peroxidase. 5-Aminosalicylic acid was used as the enzyme substrate and the absorbance measured at 474 nm. In this assay, as the amount of solid phase immunoglobulin is limited, the amount of enzyme bound is inversely proportional to the concentration of immunoglobulin in the test sample. With this assay IgG is detectable down to 2·5 μg/l, IgA down to 4·2 μg/l, and IgM down to 7·2 μg/l. There is undetectable cross reactivity among the immunoglobulin classes with the exception of purified IgM, which cross reacted at 1·9% with the IgG enzyme immunoassay.[7] For standardisation all results were expressed as μg immunoglobulin/mg total protein in the lavage sample. Total protein in mg/ml was measured by the Lowry method.[8]

Immunostaining for lung immunoglobulins—Lung tissue collected at necropsy was stored at −70°C. Sections were cut on a cryostat and mounted on glass slides. Endogenous peroxidase was blocked with 1·6% hydrogen peroxide in absolute methanol for 20 minutes. Fc receptors were blocked with normal horse serum diluted 1/50 in isotonic saline for 20 minutes. Antihuman IgG (HB-60) and antihuman IgM (HB-57) were obtained from American Type Culture Collection, Maryland, and used as neat supernatant. The IgA monoclonal antibody (H-11) is reactive with human IgA secretory component. It was supplied as ascites and diluted 1/50 for use. The antibodies were applied for two hours, followed by the secondary antibody (horse antimouse IgG-biotin conjugate) for 30 minutes. Avidin-Biotin complex (Vector Laboratories) was applied for one hour and the complex developed with 0·05% diaminobenzidine hydrochloride (Sigma Chemicals) and 0·01% hydrogen peroxide for 10 minutes. Nuclei were counterstained with Mayers progressive haematoxylin for 30 seconds. All incubation steps were performed at room temperature, with the sections washed three times in TRIS hydrochloric acid buffer 0·05 mol/l pH 7·6 between each step. Positive cells on immunohistological staining were identified by two observers through a double headed Olympus microscope with a ×25 objective. On average 20 fields were studied per specimen. Results were expressed as the total number of positive cells per field divided by the number of fields studied and multiplied by 100.

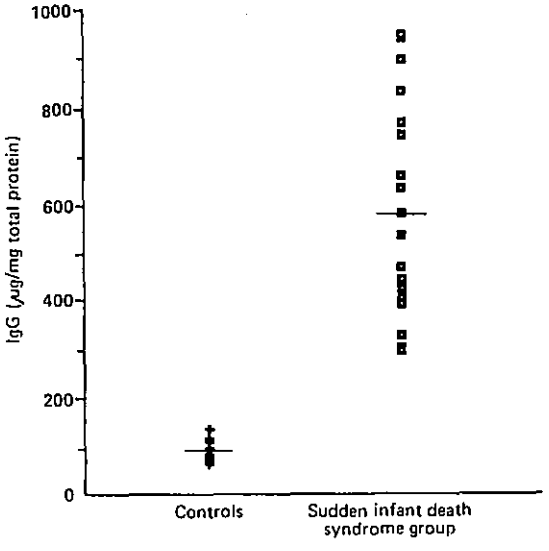

FIG 1—*Pulmonary lavage fluid concentrations of IgG (expressed as μg/mg total protein) in eight controls and 16 victims of sudden infant death syndrome. Roughly half of lavage fluid protein in sudden infant death syndrome group was IgG*

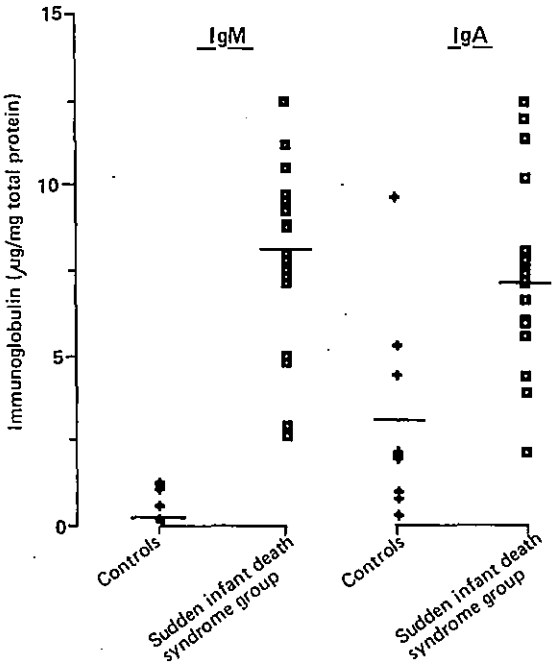

FIG 2—*Pulmonary lavage fluid concentrations of IgM and IgA in eight controls and 16 victims of sudden infant death syndrome. There was significantly more of both immunoglobulins in victims of sudden infant death syndrome than controls*

Statistics—Results are expressed as the mean and one standard deviation (1SD). As the immunoglobulin results did not conform to a normal distribution, the Mann-Whitney U test was used to compare values between the sudden infant death syndrome and control groups.

Results

Lung lavage samples—IgG was present in the lavage samples of all subjects, with remarkably high values in the sudden infant death syndrome group; just over half the total protein in the lavage samples was IgG (fig 1). The mean IgG concentration in the sudden infant death syndrome group was 578 (216) μg/mg total protein and in the controls 93 (22) μg/mg ($p<0·005$). IgA and IgM concentrations were similar and quantitatively much lower than the IgG concentrations. The mean IgA concentration in the lavage fluid in the sudden infant death syndrome group was 7 (2) μg/mg total protein and in the controls 3 (3) μg/mg ($p<0·005$) (fig 2). The mean IgM concentration in the sudden infant death syndrome group was 8 (3) μg/mg total protein and in the controls 0·5 (0·4) μg/mg ($p<0·005$) (fig 2). Protein concentrations in the lavage samples were not significantly different between the two groups

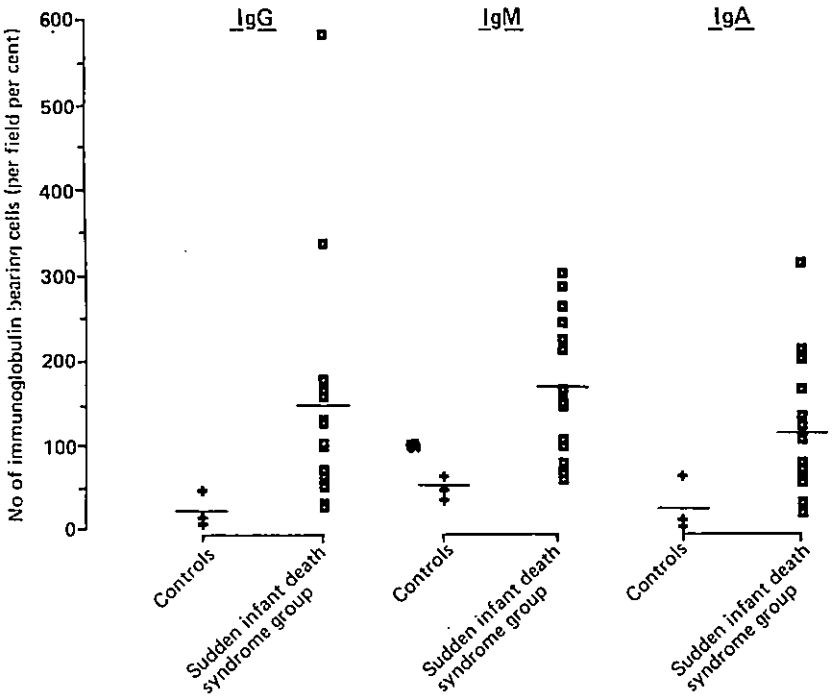

FIG 3—*Numbers of positively stained (immunoglobulin bearing) cells per field per cent in frozen sections of lung tissue in four controls and 16 victims of sudden infant death syndrome. All three immunoglobulins were expressed more often in sudden infant death syndrome group*

(1·39 (0·6) g/l in the sudden infant death syndrome group, 1·54 (1·1) g/l in the controls).

Lung immunohistory—Positive cellular staining for immunoglobulins was evident in the terminal airways and alveolar interstitium and was extensive in victims of the sudden infant death syndrome (fig 3). The mean numbers of IgG positive cells on immunohistological staining expressed per field per cent were 151 (140) in the sudden infant death syndrome group and 26 (16) in the controls ($p<0·005$). For the IgA secretory component there were 119 (76) positive cells in the sudden infant death syndrome group and 29 (33) in the controls ($p<0·05$). Similarly, for IgM there were 176 (78) positive cells in the sudden infant death syndrome group and 53 (14) in the controls ($p<0·005$). At the cellular level the staining pattern was diffuse, not granular, and distributed throughout the cytoplasm, not solely membrane staining. In general positive cells were diffuse throughout the section, though in a few sections in the sudden infant death syndrome group there were clumps of IgA or IgG positive cells around terminal airways. The staining suggested that they were plasma cells.

Discussion

In this paper we have shown by two separate methods (analysis of pulmonary lavage fluid and pulmonary immunohistological staining) that there is a difference in the amounts of immunoglobulin present in the lungs of children who have died of the sudden infant death syndrome compared with controls. The concentration of IgG in lavage fluid was very high and the number of pulmonary interstitial and terminal airway plasma cells that expressed IgG was increased in the sudden infant death syndrome. In addition, in comparison with the controls over half the lavage fluid protein was IgG, there was an increase in lavage fluid and cellular IgM, and there was a smaller but significant increase in the IgA secretory component. These differences were apparent whether the lavage fluid immunoglobulin concentration was expressed as μg immunoglobulin/mg total protein or mg immunoglobulin/ml lavage fluid (data not shown).

In a recent study by our group of respiratory tract immunoglobulins from ventilated neonates IgG was found to be the predominant immunoglobulin.[9] In this series victims of the sudden infant death syndrome were on average one month younger than the controls. Data on lower respiratory tract immunoglobulin concentrations in normal children are not available. Concentrations in the serum and lower respiratory tract of intubated neonates, however, suggest a decline in IgG values with increasing age and a slow increase in IgA and IgM.[9] These differences are not significant over one month.

Previous work also by our group on lung lavage cell phenotype in the sudden infant death syndrome has shown a difference between victims of the syndrome and controls.[6] The relevance of this difference (lack of CD14A reactivity in the sudden infant death syndrome group) is uncertain but it is compatible with cellular activation (N Hogg (London), personal communication).

There has been little work on pulmonary immune mechanisms in the sudden infant death syndrome. A study by Ogra *et al* in 1975 using a qualitative (radial gel diffusion) rather than quantitative method showed IgG and IgM to be present in lavage fluid in the sudden infant death syndrome, but secretory component to be absent in pulmonary tissue.[10] Ackermann *et al*, in agreement with our findings, detected significantly increased IgG expression in pulmonary tissue from victims of the syndrome with a fluorescein labelled sheep antihuman IgG antibody.[11,12]

Our studies suggest that there is altered immunological function in the sudden infant death syndrome. There is alteration of cellular phenotypes and a gross increase in IgG and IgM concentrations in lung lavage fluid. The relevance of these changes is not clear. Possibly an unrecognised respiratory pathogen is stimulating high immunoglobulin concentrations in the respiratory tract. More probably, however, a dysregulation of immunoglobulin production stimulated by a trivial infection might serve to "trigger" the attack in an infant at risk by exposing antigens or modulating the immune response.[13] It has been postulated, for example, that the sudden infant death syndrome may be a modified form of local anaphylaxis occurring in the lungs, possibly mediated by IgG[14]; infection might produce or expose the appropriate antigen for this type of reaction in susceptible children.

Though extravasation of IgG might be due to an anaphylactoid type of reaction, this could not account for the numbers of plasma cells seen in tissues where they are rarely if ever present. This finding points to local production of immunoglobulin. The evidence, both epidemiological and from this study, suggests that the respiratory tract is the prime target organ in the sudden infant death syndrome. Further investigation of pulmonary immunological responses is required.

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Serious eye injuries due to war games

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"War games" are an outdoor activity combining recreation, military style manoeuvres, and fantasy. Combatants in the games fire gelatin pellets filled with dye at each other from powerful air guns. War games' weaponry developed from paint guns used by forestry workers to mark trees for felling. These guns are powered either by carbon dioxide cartridges or by rounds detonated by percussion. Gas cartridge weapons are not classified as firearms in the United Kingdom, in contrast to rounds detonated by percussion. The ammunition comprises pellets filled with paint, and the guns are remarkably realistic, resembling revolvers, semiautomatic handguns, rifles, or machine pistols. Muzzle velocities of up to 134 m/s and energies of 10 J are possible with rates of fire of 1200 rounds a minute.[1] Combatants are issued with protective goggles, and shots aimed at the head are prohibited.

Case reports

Although goggles should be worn and the head avoided, during July 1987 to February 1988 we saw six cases of serious ocular injury resulting from war games. The table summarises these cases.

Comment

Serious injuries due to war games were first reported in Canada in 1984.[2,3] To our knowledge they have not been reported in Britain, presumably because this new pastime is not yet so popular in this country. Easterbrook *et al* reviewed data collected by the eye safety committee of the Canadian Society of Ophthalmology and described 26 cases, including one of a ruptured eye, which was eventually excised.[2] They noted that though eyeguards had been provided in all instances, none were in use at the time of injury. Subsequently two isolated cases were reported from the United States[4,5]; in one goggles were being worn but did not prevent hyphaema, vitreous haemorrhage, and a retinal tear.[5]

Goggles were supplied to all our six patients; a lens from one pair, however, dropped out spontaneously, and in three cases the goggles were removed for extra comfort and visibility before injury. In the remaining two patients who were wearing goggles both injuries resulted from the plastic pellet dislocating the lens from the frame and driving it on to the eye. The toughened protective glasses and rubber rimmed industrial goggles were inadequate, and single piece polycarbonate eye protectors such as those recommended for racket sports seem more suitable.

The injuries reported were of a blunt, non-penetrating type normally associated with fairly low kinetic energies further dissipated by goggles, when worn. Permanent visual loss, however, may result from these games as the weapons have sufficient muzzle velocities to cause penetration of the eye. Moreover, though the retained subconjunctival dye in case 4 did not seem to be toxic, blunt ocular injury carries considerable morbidity. Emergency admission to hospital was required in three of our six cases to treat raised intraocular pressure and to minimise the risk of rebleeding hyphaema. All six patients required prolonged follow up to identify and treat delayed complications such as secondary glaucoma, contusion cataract, recurrent corneal erosion syndrome, retinal pigment epithelial degeneration, and retinal detachment.

We gratefully acknowledge the help of Mr D Pryor, Metropolitan police laboratory, firearms section.

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Details of six cases of ocular injury due to weapons used in war games

Case No	Age (years)	Wearing goggles	Emergency admission to hospital	Initial visual acuity	Presentation	Final visual acuity (months later)
1	16	No	Yes	Hand movements	Corneal abrasion, hyphaema, contusion cataract, contusion of retina, and subsequent atrophy of retinal pigment epithelium	6/12 (Six months; after extraction of cataract and insertion of aphakic contact lens)
2	35	Yes	Yes	6/12	Conjunctival laceration, hyphaema, drainage angle recession, rupture of iris sphincter, and contusion of retina	
3	28	Yes	No	6/6	Hyphaema, corneal abrasion	6/6 (Two months)
4	38	No	Yes	6/24	Conjunctival laceration, retained subconjunctival vegetable dye, corneal abrasion, hyphaema, rupture of iris sphincter, vitreous haemorrhage, contusion of retina, atrophy of retinal pigment epithelium	6/12 (Three months)
5	24	No	No	6/5	Hyphaema, transient raised intraocular pressure, vitreous haemorrhage, retinal tear (treated by cryopexy)	6/6 (Three months)
6	19	No	No	6/5	Hyphaema, drainage angle recession	6/5 (One month)

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Original works

Chlamydia and sudden infant death syndrome. A study of 166 SIDS and 30 control cases

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Summary. Chlamydia inclusions could be demonstrated by an immunofluorescence assay in formalin-fixed lung sections in 32 of 166 cases (19.4%) of Sudden Infant Death Syndrome (SIDS) and in the lungs of only 1 of 30 infants with a known cause of death (3.3%). The difference is statistically significant ($P = 0.04$). *Chlamydia trachomatis* is an agent of pneumonia in 1–4 month-old infants who have acquired the disease from an infected cervix during birth, but other chlamydia species are also capable of causing pneumonia. The lung sections of the 32 chlamydia positive SIDS cases did not show typical histological signs of pneumonia. Even though chlamydia inclusions were detected in the lungs of 32 SIDS cases a causal relation between chlamydia infection and SIDS could not be demonstrated.

Key words: Sudden Infant Death Syndrome – *Chlamydia* – Bacteria – Diagnosis – Immunofluorescence

Zusammenfassung. *Chlamydia*-Einschlüsse konnten mit Hilfe eines Immunfluoreszenz-Ansatzes in formalinfixierten Lungenschnitten in 32 von 166 Fällen (19,4%) des Syndroms des plötzlichen Kindstodes und in lediglich einem von 30 Fällen von Kindern mit bekannter Todesursache (3,3%) festgestellt werden. Der Unterschied ist statistisch significant ($P = 0{,}04$). Chlamydia trachomatis ist ein Erzeuger von Pneumonien bei 1–4 Monate alten Kindern, die die Erkrankung während der Geburt aufgrund einer infizierten Cervix acquiriert haben, aber andere Chlamydia-Arten sind auch imstande, eine Pneumonie zu verursachen. Die Lungenschnitte von 32 Chlamydia-positiven SIDS-Fällen zeigten keine typischen histologischen Zeichen der Pneumonie. Obwohl jedoch Chlamydia-Einschlüsse in den Lungen von 32 SIDS-Fällen gefunden wurden, konnte eine kausale Beziehung zwischen Chlamydia-Infektion und SIDS nicht nachgewiesen werden.

Schlüsselwörter: Syndrom des plötzlichen Kindstodes – *Chlamydia* – Bakterien – Diagnose – Immunfluoreszenz

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Introduction

In Western countries about half of all postneonatal deaths are classified as Sudden Infant Death Syndrome (SIDS). The cause of SIDS is still unknown in spite of an increased public awareness and intensified research and its prevalence is unchanged [1]. In most of the SIDS cases the autopsy shows no pathological changes, but some cases have minor signs of infections in the respiratory organs insufficient to explain the cause of death. A number of the infants have had history of coughs and other symptoms of minor respiratory infection preceding death [2] but no causal relation between infectious agents and SIDS has until now been demonstrated.

Chlamydia trachomatis is among the most common agents of lower respiratory infections during the first three months of infancy [3, 4], but no studies of the relation between this microorganism and SIDS have ever been performed. In this paper a possible connection between chlamydia and SIDS was studied by determinating the occurrence of chlamydia inclusions in the lungs of these infants.

The genus *Chlamydia* consists of three species, *Chlamydia trachomatis, Chlamydia psittaci* and *Chlamydia pneumoniae. C. trachomatis* is a human pathogen causing oculogenital infections and pneumonia in 3–4 month-old infants [5]. *C. psittaci* is mainly an animal pathogen, but in man it produces ornithosis which occurs as a systemic infection with a severe pneumonia [5]. *C. psittaci* has also been associated with abortion in women [6, 7].

C. pneumoniae causes respiratory infections including pneumonia [8]. Chlamydia is an obligate intracellular bacteria with a biphasic life cycle. The characteristic chlamydia morphology is represented by the inclusion, which is the metabolically active part of chlamydia. We have previously described a method to detect chlamydia inclusions in postmortal formalin-fixed tissue with an immunofluorescence assay using two genus-specific monoclonal antibodies [9]. In this study the frequency of chlamydia inclusions in the lungs of 166 SIDS cases and a comparable control group of 30 infants which died of known causes is described and discussed.

Materials and methods

SIDS cases. A prospective study of all cases of sudden infant death was carried out in Denmark in 1987 and 1988. According to Danish law all cases of SIDS are submitted to a postmortal medico-legal investigation and in most cases a medico-legal autopsy is performed. The autopsy rate was 95% in the years 1987 and 1988. Two hundred and seven infants between the age of 1 week and 1 year died suddenly in 1987 and 1988. The cause of death was explained by autopsy in 24 cases. Eleven cases were not autopsied due to prohibition by the parents. From the 172 autopsied infants with no known cause of death, 166 cases were selected and were classified as SIDS according to the definition "The sudden death of any infant or young child which is unexpected by history and in which a thorough post mortem examination fails to reveal an adequate cause of death" [10]. One hundred and twenty-six cases had no pathological changes, but 5 infants with histologically minor signs of viral pneumonia insufficient to explain death and 35 infants with cellular inflammatory changes considered insignificant for the death, were included in the 166 SIDS cases selected.

The age interval of the selected SIDS group in this study was between 28 days and 1 year. The age distribution of the SIDS cases was from 1 to 10 months, with 2 month-old infants making up 28% of the total and 86% aged between 1 and 4 months.

Control cases. Thirty control cases aged between 28 days and 1 year were found in the files of the Danish Institutes of Forensic Medicine from January 1 1985 and December 31 1988.

Only infants with a known cause of death were selected and included 7 cases of previous undiagnosed congenital heart disease, 2 cases of bacterial meningitis, 4 cases of cerebral disorders (2

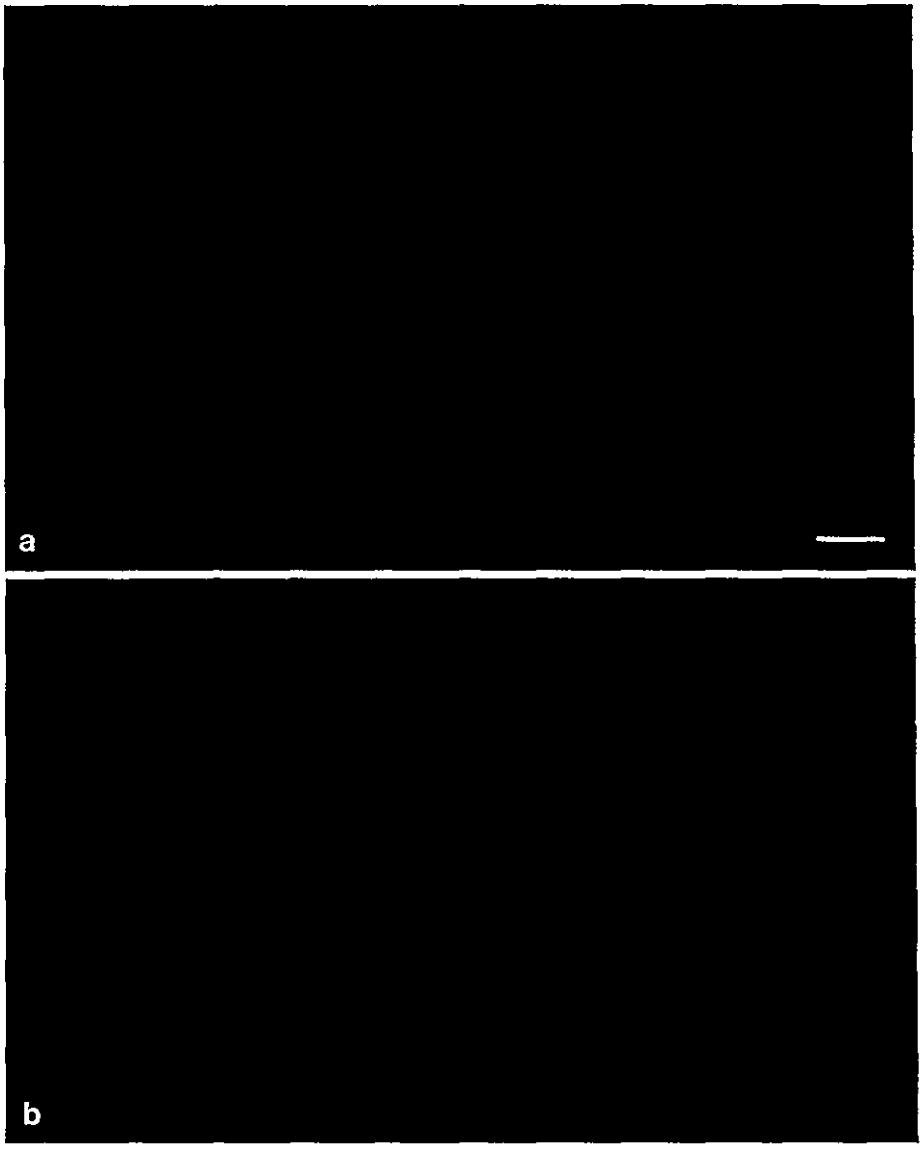

Fig. 1a Two chlamydia inclusions in the lung of one of the chlamydia positive SIDS cases. Original magnification × 500. Bar represents 10 µm. **b** The left upper inclusion from a magnified × 1500. The reticulate bodies are located in the cytoplasm around the nucleus of the host cell

thrombosis and 2 incarcerations), 5 major respiratory infections (with verified bacteriology), 1 abdominal haemorrhagic infarction, 8 accidents (domestic or traffic) and 3 homicides.

The age distribution of the infants in the control group was from 1 to 12 months, 66% were from 1–4 months old and 4 month-old infants making up 20% of the total.

Immunofluorescence method. Formalin-fixed lung sections from the SIDS and control cases were retrospectively examined for chlamydia inclusions as described by Lundemose et al. [9]. Two monoclonal antibodies 12.1 and 15.1 against the genus-specific chlamydia lipopolysaccharide (LPS) epitope were used [11]. These antibodies react only with the chlamydia-specific LPS epitope and no cross reactions occurs. Intracellular inclusions or LPS accumulated in the membrane of the infected host cell were visualized with immunofluorescence after reaction with fluorescein-conjugated anti-mouse antibody (IgG). Problems with background staining were avoided by using trypsin, rabbit serum and Evans-blue. Trypsin removes the non-specific antibody binding Fc-receptors in the tissue by digestion and the rabbit serum minimizes the non-specific antibody adsorption by competition with the specific antibody. Evans-blue was used as counterstain.

The positive immunofluorescence diagnosis in this study was exclusively based on the bright apple-green fluorescence and the characteristic morphology of the chlamydia inclusion as described earlier [9]. In all the chlamydia positive cases distinct and sharply demarcated inclusions were visualized (Fig. 1). The case was only considered positive if inclusions were seen in at least 2 of the 4 lung sections. LPS accumulated in the membrane of the infected host cells was sometimes visualized as a bright applegreen lining of the cell/epithelium, also called the alveolar lining.

Demonstration of chlamydia inclusions in the lung tissue by immunofluorescence. Four tissue sections, two from the central and two from peripheral parts of both lungs were examined for each case. The tissue sections were examined in the form of a blind trial and were all examined by the same individual. The results were reproducible in 100% of the cases when re-examined 1 day later (75% were re-examined). The positive controls were lung sections from a mouse artificially infected with *C. trachomatis* serovar L2. The negative controls were lung sections from a 45-year-old man who had died from suffocation with no histological signs of pneumonia.

Statistical analysis. Fisher's exact test was used for statistical analysis of the results observed in this study.

Results

Thirty-two of the 166 SIDS cases (19.4%) and one of the control cases (3.3%) had typical chlamydia inclusions in the lungs. The data was subjected to Fisher's exact analysis, and associations with P values below 0.05 were regarded as significant ($P = 0.04$).

All the chlamydia positive cases had 10 or more inclusions in each positive lung section, 10 cases had more than 25 inclusions and 3 cases more than 100 inclusions. The inclusions were usually seen in clusters and always in the peripheral parts of the lungs located in relation to the alveoli. In the 13 heavily (25 inclusions or more) infected cases accumulation of LPS in the membrane of the infected host cell (membrane/alveolar lining) was detected. The alveolar lining was nearly always located in the central parts of the lung.

Chlamydia positive cases were aged from 1–7 months, the first 4 months making up 84% with a peak at 1–2 months. The histological examination of the lung sections from the chlamydia positive cases did not show any signs of typical chlamydia pneumonia with inflammatory exudate in the alveoli and lymphocytic infiltration in the bronchial submucosa. There were no specific reports of symptoms of tachypnea, staccato cough and inspiratory stridor, although 6 of the 32 chlamydia positive infants were reported to have had colds and coughs immediately preceding death. One of the 3 chlamydia positive cases with more than 100 inclusions per positive lung section and 1 of the chlamydia positive cases with more than 25 inclusions per lung section had minor signs of viral pneumonia insufficient to explain death. In addition, 9 of the chlamydia positive infants with more than 25 inclusions per lung section showed non-specific lymphocytic infiltration in the lungs. None of these histological pictures were serious enough to explain the cause of death. The remaining 21 of the chlamydia positive cases showed no evidence of infectious diseases either in the medical history or in the histological examination. Forty of the 166 cases in the total SIDS group had inflammatory cellular changes in the lungs insufficient to explain death. Colds and coughs were reported in 43 of the 166 cases.

The single chlamydia positive infant in the control group was a 8 1/2 month-old female with Down's Syndrome. The girl had a severe congenital heart malformation, which was considered the cause of death. The histological examination of the lungs showed signs of bronchopneumonia. The immunofluorescence examination showed more than 10 chlamydia inclusions per positive lung section. Fourteen of the 30 cases in the control group had non-specific cellular infiltrations or slight focal bronchopneumonia in the lungs as a secondary finding to the primary cause of death.

Discussion

The occurrence of chlamydia inclusions in the lungs of a SIDS group has been examined and compared with a control group. Due to the high overall autopsy rate in cases of infant deaths in Denmark, the SIDS group as well as the control group was well-defined. A simple and easily performed immunofluorescence technique has been used which is applicable on formalin-fixed tissue sections [9]. It was found that 32 of the 166 SIDS cases examined were positive for chlamydia inclusions. Only 1 child was found positive in the control group. The difference between the SIDS group and the control group was statistically significant ($P = 0.04$). The P value was relatively higher than expected due to the low number of cases in the control group. However, we were not able to allocate more than 30 infants to the control group and could only have increased the number by expanding the age and time interval or by including material from ordinary pathological autopsies.

The immunofluorescence assay was selected as the diagnostic tool, since cultivation from autopsy material is difficult because of postmortal loss of viability of the chlamydia. Genus-specific monoclonal antibodies against LPS were selected instead of the species-specific monoclonal antibodies against the Major Outer Membrane Protein, because the non-protein origin of LPS allows

treatment with the background-reducing trypsin which is very important for the assay [9]. Furthermore LPS is in contrast to proteins, resistent to proteolysis and to postmortem autolysis [9]. The membrane lining observed in some sections is probably caused by LPS incorporated into the plasma membrane of the infected host cell during infection [12]. Birkelund et al. [13] have shown that chlamydial elementary bodies treated with monoclonal LPS antibodies liberate LPS from the surface into the surroundings. Thus an alternative explanation to the formation of the membrane lining could be that LPS is liberated from the infected cell during infection. The membrane lining seen in the sections from the central part of the lungs could thus represent free LPS removed by the alveolar macrophages.

Conjunctivitis and nasopharyngeal infections in infants of *C. trachomatis* infected mothers has been observed and it has been reported that this may result in pneumonia [14]. The disease is usually mild and does not require hospitalization, but it reportedly accounts for approximately one third of the cases of pneumonia in hospitalized infants from 1–6 months of age and may occasionally be life-threatening [15]. Impairment of lung function may persist for a longer period than after a viral pneumonia [16]. The chlamydia positive SIDS cases in our study were aged between 1–7 months, 86% between 1–4 months in which *C. trachomatis* pneumonia usually occurs. The age distribution of the SIDS group and the control group was almost identical.

Although *C. trachomatis* is the classic agent of chlamydia pneumonia in young infants, the 2 other chlamydia species may be responsible for some of the inclusions detected in the lung sections of the chlamydia positive cases. The applied immunofluorescence assay does not permit distinction between the 3 chlamydia species. As *C. pneumoniae* is a new chlamydia species capable of producing lower respiratory diseases transmitted by droplet infection, it might be considered a possible source of at least some of the inclusions observed in the lungs of the SIDS cases. *C. psittaci* in humans is associated with severe pneumonia, but has also been reported to produce acute placentitis and abortion in women, where both the mother and the fetus have been infected [17]. Therefore *C. psittaci* is difficult to exclude as a possible agent of some of the inclusions found in the lungs of the chlamydia positive cases.

In Denmark pregnant women are not routinely screened for genital chlamydia infections and gynaecological and obstetric data on the mothers, including venereal status, preceding the births of the infants included in this study are therefore not available. Several authors [for ref. see 15] have shown that approximately 7%–12% of cervices are infected with *C. trachomatis* before delivery. Approximately 2 out of 3 infants who are exposed to *C. trachomatis* acquire the infection, and pneumonia will develop in about 10%–20% [18]. Using these figures, the expected frequency of *C. trachomatis* pneumonia in this study should have been about 1% to 2%. In the present study we found 3.3% positive for chlamydia in the control group. The difference between the expected and the actual chlamydia frequency in the control group could either be caused be the presence of chlamydia inclusions from the other 2 chlamydia species or simply be due to the small number (30) in our control group. The high frequency of chlamydia in the SIDS cases could theoretically be regarded as a normal finding, explained by a 100% transmission rate from the infected mother to the infant, but since a similar frequency was not seen in the control group, the occurrence of chlamydia in the SIDS cases must be regarded as significant.

An association between chlamydia and SIDS has been noted before but was not further examined [19]. The chlamydia organism has been well studied and it seems odd that chlamydia infection in SIDS infants has been overlooked before. However, cultivation of chlamydia from autopsy material is, as already mentioned, difficult and a direct antigen detecting method applicable on postmortem formalin-fixed tissue, has not been described until recently [9].

We did not find any histologically verified signs of typical chlamydia pneumonia in the 32 chlamydia positive SIDS cases or in the 1 chlamydia positive control case. Nor did we find any cellular reactions in the lungs of these infants adequate to explain the cause of death. Twenty-one of the positive infants did not have any signs of pulmonary inflammation and 11 infants with more than 25 inclusions per lung section had only non-specific lymphocytic infiltration or minor histological signs of viral pneumonia. Based on this observation it could be speculated whether some infants who may be incapable of producing an adequate response to a microorganism could die of a chlamydia infection, without significant histological signs of inflammation.

Evidence of respiratory inflammation has been found in a considerable proportion of SIDS cases [20, 21]. Some investigators have sought the explanation in a specific microorganism. Püschel et al. [22] examined the parotid gland and/or the submandibular gland for Cytomegalovirus (CMV) in 255 SIDS cases by means of HE staining, immunohistochemical analysis, in situ hybridization and electron microscopy. Typical cytomegalic inclusions were recognized in 10% of the cases. A localized CMV infection of the salivary glands does not adequately explain the sudden death of these infants, but the investigators emphasize that cytomegaly may influence the immunological status of the organism. Telford et al. [23] found significantly higher rates of streptococcal and enterobacterial carriage in the nasopharyngeal flora in a SIDS group than in a matched living control group, indicating a disordered nasopharyngeal flora in SIDS cases. However, these studies do not deal with a control group of infants at the same age and dying in the same period as the SIDS group examined.

It is difficult to establish a causal relationship between certain microorganisms and SIDS. However, in support of a causal relation between chlamydia infection and SIDS, we have found a disseminated chlamydia infection in a SIDS infant who died in 1989. Chlamydia inclusions were found in the lungs, heart, liver and prostate gland, with an inflammatory response only in the prostate gland. We have not examined all the organs from the SIDS cases in this study, but are in the future planning to ex-

amine the degree of dissemination of the chlamydia infection in the 32 SIDS cases with chlamydia inclusions in the lungs. Whether a disseminated infection with chlamydia or other microorganisms is the cause of death in some SIDS cases as a result of an inadequate response to the infection needs further investigation.

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Association of Primary *Pneumocystis carinii* Infection and Sudden Infant Death Syndrome

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To delineate clinical and histological features of the first *Pneumocystis carinii* infection affecting the immunocompetent host, *P. carinii*–specific histological stains were performed on autopsy lung specimens from 534 consecutive pediatric patients (those with AIDS and malignancies were excluded) in Santiago, Chile. *P. carinii* clusters were found in 4 (25%) of 16 infants who died of no apparent cause at arrival to the emergency department, and in 10 (2.9%) of 342 infants who died of multiple conditions at the hospital ($P = .002$, Fisher's exact test). This prompted us to analyze additional series of infants with sudden infant death syndrome (SIDS). In 161 additional SIDS cases, 47 (35.1%) of 134 infants from Chile and 4 (14.8%) of 27 infants from Oxford, United Kingdom, were found to have *P. carinii* clusters in the lungs. The quantity of *P. carinii* cysts was small compared with the numbers seen in immunocompromised hosts with *P. carinii* pneumonitis. This study provides histological evidence that primary *P. carinii* infection is associated with SIDS.

There is well-documented serological evidence that up to 94% of normal immunocompetent children have detectable antibody to *Pneumocystis carinii* by 30 months to 4 years of age [1, 2], which indicates that primary *P. carinii* infection is one of the most common infections in humans and that exposure occurs early in life. Experimental evidence shows that the host response pattern associated with primary *P. carinii* infection in otherwise healthy animals is milder [3–5] than that associated with the usually massive infection seen in an immunocompromised host. Data for humans are scant: *P. carinii* in low numbers or mild focal pneumonitis has rarely been reported as an autopsy finding for presumably immunocompetent children, and then the infection has been judged to be latent, incidental organisms [6]. In contrast, there are abundant autopsy reports of interstitial plasma cell pneumonia in certain groups of debilitated, undernourished, or premature infants, and reports of *P. carinii* pneumonia in infants and children with primary and secondary immunodeficiency syndromes [7, 8].

Cross-sectional studies of children's lungs at autopsy might provide histological support for the assumption, based on serology, that primary *P. carinii* infection is a common occurrence in small children. Furthermore, a correlate with diagnosis before death might provide insight to the clinical presentation of primary infection in immunocompetent infants and children.

Because specific stains are needed to identify *P. carinii* in tissue samples, we undertook a prospective search for *P. carinii* by studying autopsy lung specimens from 534 consecutive children (those with AIDS and malignancies were excluded) that were obtained over a 6-year period at 2 major pediatric hospitals in Santiago, Chile. *P. carinii* was detected more frequently in infants who were dead on arrival at the emergency department and had an autopsy diagnosis compatible with sudden infant death syndrome (SIDS) than in children who died of multiple conditions at the hospital. These findings prompted us to expand our study to include an additional 134 infants in Chile who died at home and had a postautopsy diagnosis of SIDS, and 27 infants in Oxford, United Kingdom, who died of SIDS.

Methods

Lung specimens. A total of 695 autopsy lung samples were studied from infants and children in 4 different series. Series 1

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comprised 534 consecutive pediatric patients (those with malignancies and AIDS were excluded) who were autopsied between January 1990 and December 1996 at the Department of Pathology, Luis Calvo Mackenna Children's Hospital, and the Department of Pathology, Roberto del Rio Children's Hospital, in Santiago. Series 2 comprised 94 infants with SIDS who were autopsied at the Legal Medicine Institute of Chile during 1996 and 1997; series 3, 40 infants with SIDS who were autopsied at the Department of Pathology, Exequiel Gonzalez Cortés Children's Hospital in Santiago between 1990 and 1993. Series 4 comprised 27 infants with SIDS who were autopsied at the Department of Pathology, John Radcliffe Hospital, University of Oxford, Oxford, from 1996 to 1998.

Formalin-fixed paraffin-imbedded lung specimens were provided by pathologists from each institution. Age, circumstances of death, and postautopsy diagnosis were recorded when available. SIDS was diagnosed if there was no recognized premortem disease, no significant microscopic or macroscopic pathological findings, and toxicology studies were negative.

Control subjects. All 342 infants who were aged between 5 days and 12 months at the time of death at the hospital were identified from the original 534 infants in series 1. These were selected as control subjects for the purpose of statistical comparison with the age-matched infants who died suddenly at home. Newborns aged <5 days were excluded.

Processing of lung specimens and stains. Lung tissue specimens were sectioned (5 μm) and stained with Grocott-Gomori methenamine–silver nitrate and hematoxylin-eosin stains. Slides from series 1 were examined by investigators blind to the diagnosis of SIDS, and slides from series 2 and 3 were examined by investigators aware of the diagnosis of SIDS. Slides in cases from Oxford were examined by investigators blind to the diagnosis of SIDS who also analyzed slides for possibly immunocompromised or immunocompromised patients with unknown *P. carinii* status. Specimens were examined by 2 different investigators (S.L.V. and J.C.W., C.P., or P.M.) in all cases. Discordant results were discussed, and cases were labeled as positive only if typical *P. carinii* cysts in clusters of 3 or more organisms were seen by both investigators. A third investigator reviewed positive cases (W.T.H. for Chilean samples, and S.G. for Oxford samples). Positive slides were subsequently stained with monoclonal antibody 3F6 (Dako Diagnostics, Carpinteria, CA), which recognizes an 82-kDa protein present in the cyst wall that is not altered by formalin or paraffin; all positive cases were confirmed by both methods (figure 1).

Clinicopathologic correlation. To gain insight into the clinical history and to better describe the histopathologic pattern of primary *P. carinii* infection in these children, the criteria described by Price and Hughes [9] for children with malignancies were retrospectively applied to *P. carinii*–positive patients with SIDS. Briefly, this scale of lung involvement with clinical correlation considers 2 asymptomatic stages and 1 symptomatic stage of *P. carinii* infection. Asymptomatic stages were described as isolated cysts with no parenchymal reaction of the lung (stage 1) or desquamation of organisms into the alveolar lumen with an increasing number of *P. carinii* and minimal or no inflammatory response in alveolar septa (stage 2). The symptomatic stage was defined as a host response consisting of alveolar desquamation and lymphocytic and plasma cell alveolar infiltrates (stage 3). Stage 3 was found by these investigators to correlate with clinical symptoms and radiographic signs of *P. carinii* pneumonitis in children with different types of cancer.

Statistical analysis. To compare the incidence of *P. carinii*–positive and –negative lung samples among infants who died at home of SIDS with the incidence among those who died at the hospital of multiple conditions, we used Fisher's exact test (using Epi-Info version 6; Centers for Disease Control and Prevention, Atlanta, GA). Control subjects were compared with infants with SIDS from series 1 and also with infants from series 2 and 3 combined. $P < .05$ was considered statistically significant.

Results

Series 1. Of 534 lung tissue specimens from consecutive pediatric patients that were blind to investigators with respect to age and diagnosis, 16 (3%) were found to be positive for *P. carinii* clusters. Primary autopsy diagnoses for these children were as follows: bronchopneumonia, 5 children; SIDS, 4; bronchitis, 1; generalized lipidosis, 1; and no diagnosis available, 1. The following underlying diseases suggestive of an immune defect were present in 4 patients who also had bronchopneumonia as a secondary diagnosis: severe combined immunodeficiency syndrome, congenital medullary aplasia, mucocutaneous candidiasis, and fulminant hepatitis. Age distribution and primary autopsy diagnoses for these patients are shown in table 1. *P. carinii* was detected in 4 (25%) of 16 infants who were dead at arrival to the emergency department and had a postautopsy diagnosis of SIDS compared with 10 (2.9%) of 342 infants who were aged between 5 days and 1 year and died of multiple conditions at the hospital ($P = .002$, Fisher's exact test). On the basis of this observation, we elected to examine a larger number of infants with a postautopsy diagnosis of SIDS.

Series 2–4 and control subjects. We examined an additional 134 infants with a primary autopsy diagnosis of SIDS who were autopsied at different hospitals in Santiago (series 2 and 3) and 27 infants who died of SIDS and were autopsied at a hospital in Oxford (series 4) (table 2). Ages of these infants ranged from 20 to 575 days (mean, 95 days; median, 60 days). Ages of control subjects ranged from 5 to 365 days (mean, 88 days; median, 60 days); control subjects were matched according to the age criterion for the diagnosis of SIDS.

Ten (2.9%) of 342 controls had *P. carinii* clusters compared with 47 (35.1%) of 134 Chilean infants with an autopsy diagnosis of SIDS in series 2 and 3 ($P = .0000001$, Fisher's exact test). Four (14.8%) of the 27 infants who died of SIDS in Oxford were found to have *P. carinii* clusters by histological analysis (table 2).

Lung reaction, extent of P. carinii *infection, and retrospective correlation with clinical manifestations before death.* Of 55 *P. carinii*–positive patients with SIDS, 13 were not evaluable because the specimens had extensive postmortem autolysis. The clinicopathologic correlation criteria developed by Price and Hughes [9] were applied to 42 evaluable cases. Twelve and 25

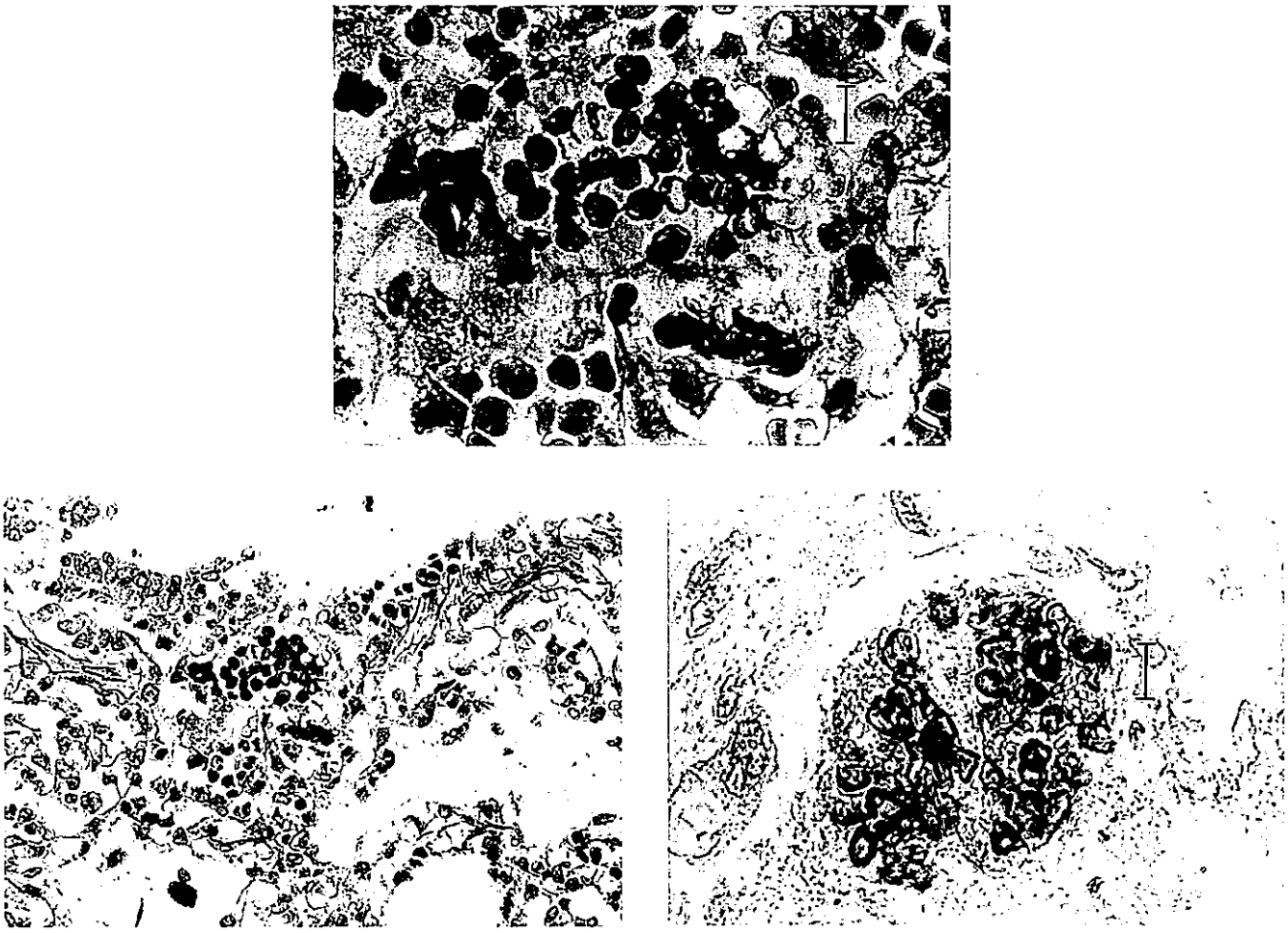

Figure 1. *A, Pneumocystis carinii* clusters in lung tissue specimen from a 2-month-old infant diagnosed with sudden infant death syndrome (SIDS) (Grocott-Gomori methenamine–silver nitrate stain; original mag, ×330; bar, 10 μm). *B,* Smaller magnification (×60) of *A,* illustrating that number of *P. carinii* clusters in patients with SIDS is few. *C,* Immunohistochemical analysis with monoclonal antibody 3F6 (Dako Diagnostics, Carpinteria, CA) of lung tissue specimen from a 4-month-old infant diagnosed with SIDS that reveals *P. carinii* cluster filling an alveolus (original mag, ×330; bar, 10 μm). Grocott-Gomori methenamine–silver nitrate stain is generally considered standard for detection of *P. carinii* in tissue specimens. It correlates well with immunohistochemical analysis with monoclonal antibody 3F6. *P. carinii* was detected by both techniques in all cases considered positive.

cases were categorized as stages 1 and 2, respectively (together, 88.1%), and 5 (11.9%) were categorized as stage 3, which suggests previous symptomatic disease.

Discussion

This study provides histological evidence of mild infection by *P. carinii* in presumably normal immunocompetent infants, a finding in agreement with serological evidence that most normal children are exposed to *P. carinii* at an early age [1, 2]. Mild, naturally occurring *P. carinii* infection has previously been observed in other mammals shortly after weaning: rabbits [3, 4] and piglets [5]. The young age of the patients and the characteristically mild histological pattern encountered suggest that our findings correspond to primary infection rather than to reactivated or secondary infection which has been histologically well described for the immunocompromised host [7–12].

This study also suggests an association between primary *P. carinii* infection and SIDS (table 2). A small number of reports of cases of mild, focal *P. carinii* pneumonitis in infants with SIDS in Germany, the United States, and Chile in the 1950s [6, 10–12] provide further support of this association. In this study, *P. carinii* was also found in a relatively high proportion of patients with SIDS in Santiago and Oxford. Some innate flaws in the study must be considered. In series 2 and 3, slides were examined by investigators aware of the diagnosis of SIDS. To further assess the statistical significance found in series 1, the proportion of *P. carinii*–positive cases in series 2 and 3 was compared with that of *P. carinii*–positive control subjects (table 2); however, deaths in control subjects were not sudden, and

Table 1. Age distribution, primary autopsy diagnosis, and positivity for *Pneumocystis carinii* for 534 consecutive pediatric patients (those with AIDS and malignancies were excluded) autopsied from 1990 to 1996 at 2 children's hospitals in Santiago, Chile.

Primary autopsy diagnosis	No. of patients per age at time of death (no. positive for *P. carinii*)					
	<5 d	5 d to 1 y	1–2 y	>2 y	NA	Total
Pulmonary (bronchopneumonia and others)	8	68 (5)	10	8	2	96 (5)
Heart (congenital and others)	8	111	5	12	4	140
CNS	3	9	2	2	1	17
Gastrointestinal	2	14	1	2	2	21
Various immunodeficiencies	0	4 (3)	0	4 (1)	0	8 (4)
Prematurity	32	39	0	0	2	73
SIDS	0	16 (4)	0	0	0	16 (4)
Others	6	47 (1)	3	7	4 (1)	67 (2)
NA	13	50 (1)	4	5	24	96 (1)
Total	72	358 (14)	25	40 (1)	39 (1)	534 (16)

NOTE. Lung tissue sections were examined by Grocott-Gomori methenamine–silver nitrate staining, and positive specimens were also analyzed by immunohistochemical technique. NA, not available; SIDS, sudden infant death syndrome.

cases were not matched with respect to underlying health status, prior drug therapies, and awareness of the diagnosis by investigators examining slides. The samples from Oxford (series 4) demonstrated that these findings were not a local phenomenon restricted to Chile; and so have much wider implications.

Small numbers of *P. carinii* organisms found in infants with SIDS do not necessarily represent the onset of primary *P. carinii* infection; these organisms could correspond to a phase of *P. carinii* clearance that may take up to 1 year [13]. Therefore, a well-defined control group is needed in further studies to document the relevance of a potential pathogenic role of *P. carinii* in a proportion of SIDS cases.

A possible explanation for the pathogenic role of *P. carinii* in some infants with SIDS is that it reduces the level of pulmonary surfactant. This hypothesis is supported by evidence in both experimental models and studies of humans that showed that *P. carinii* infection leads to a decrease in the level of pulmonary surfactant [14–16]. Furthermore, a decreased surfactant level has been recently shown in an animal model to be directly related to *P. carinii* growth and occurs at early stages of *P. carinii* development [14]. Relevant to this study, infants with a postautopsy diagnosis of SIDS also have been consistently found to have decreased levels of surfactant [17–19]. In 1985, Talbert and Southhall [20] first hypothesized that a decrease in surfactant level may be a mechanism that triggers sudden death in infants when it occurs at a critical stage of their lung development. Our documentation of *P. carinii* in a relatively high proportion of SIDS cases suggests that *P. carinii* might play a role, alone or as an accompanying pathogen, in the decreased level of pulmonary surfactant that is documented in SIDS cases. Whether other pathogens that possess activity against phospholipase A_2 or other mechanisms could be implicated needs to be determined [18].

Most (37 [88.1%] of 42) infants with SIDS who were positive for *P. carinii* and were evaluated by the clinicopathologic correlate developed by Price and Hughes [9] were categorized in stage 1 or 2, thus providing postmortem evidence that primary infection was asymptomatic in most SIDS cases. In agreement with this evaluation, the load of *P. carinii* organisms in SIDS cases was mild, and clusters were difficult to find histologically.

Table 2. Positivity for *Pneumocystic carinii* in lung tissue specimens from infants and children who died at hospital and from infants with SIDS.

Autopsy series, patient group	No. of *P. carinii*–positive patients/ total no. of hospital deaths (%)	No. of *P. carinii*–positive patients/ total no. of patients with SIDS	P^a
1, cases[b]	12/518 (2.3)	4/16 (25.0)	
Controls[c] vs. SIDS cases[c]	10/342 (2.9)	4/16 (25.0)	.002
2, SIDS cases[d]		35/94 (37.2)	
3, SIDS cases[d]		12/40 (30.0)	
Controls[c] vs. 2 and 3 SIDS cases[d]	10/342 (2.9)	47/134 (35.1)	.0000001
4, cases		4/27 (14.8)	

NOTE. For a description of series, see text under Methods. SIDS, sudden infant death syndrome.

[a] Fisher's exact test.

[b] Slides were examined by investigators blind to any diagnosis. All pediatric ages (newborn to 16 years) were included. Patients with malignancies and AIDS were excluded.

[c] From series 1 (controls were aged 5 days to 1 year).

[d] Slides in series 2 and 3 were examined by investigators aware of diagnosis of SIDS.

Therefore, the terminal event of SIDS cannot be explained by these findings under the current understanding of *P. carinii* disease.

Alternatively, because *P. carinii* is largely a pathogen of the immunocompromised host, finding *P. carinii* more frequently in infants with SIDS might suggest that it marks the presence of an underlying immune defect in SIDS, just as *P. carinii* has served as a marker for HIV infection [21–25].

Previous reports indicate that *P. carinii* can present as pneumonia in immunocompetent infants aged <3 months [26] and also suggest that *P. carinii* pneumonia might be associated with apnea [27, 28]. In our study, 5 (7.3%) of 68 immunocompetent infants aged from 5 days to 1 year in series 1 had bronchopneumonia as a primary autopsy diagnosis. This proportion, which agrees with findings in other studies [26, 27, 29, 30], suggests that *P. carinii* infection should be included in the differential diagnosis of bronchopneumonia in presumably immunocompetent infants. Whether a clinically identifiable pattern is present in mild forms of primary infection occurring in infants who spontaneously recover is not known.

The data provide histological evidence of primary infection by *P. carinii* in apparently immunocompetent infants and children. They show that *P. carinii* infection is more common in infants aged <1 year who die in the community than in those who die in the hospital setting and that this infection can be asymptomatic. The high prevalence of *P. carinii* infection in infants with SIDS warrants further investigation.

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