International Journal of Pediatric Otorhinolaryngology 76S (2012) S12–S19

Contents lists available at SciVerse ScienceDirect

International Journal of Pediatric Otorhinolaryngology

journal homepage: www.elsevier.com/locate/ijporl

Foreign bodies in the airways: A meta-analysis of published papers

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ARTICLE INFO

Article history:
Available online 12 February 2012

Keywords:
Airways
Foreign body
Meta-analysis

ABSTRACT

Background: Very recently, some attempts have been made to start a systematic collection of foreign bodies (FB) in view of using them to characterize the risk of chocking in terms of size, shape and consistency of the FB. However, most of the epidemiologic evidence on foreign bodies in children comes from single-center retrospective studies, without any systematic geographical and temporal coverage. This paper is aimed at providing an estimate of the distribution of foreign body's injuries in children according to gender, age, type of FB, site of obstruction, clinical presentation, diagnostic/therapeutic procedures, complications, as emerging from a meta-analytic review of published papers.
Methods: A free text search on PubMed database ((foreign bodies) OR (foreign body)) AND ((aspiration) OR (airways) OR (tracheobronchial) OR (nasal) OR (inhalation) OR (obstruction) OR (choking) OR (inhaled) OR (aspirations) OR (nose) OR (throat) OR (asphyxiation)) AND ((children) OR (child)) finalized to identify all English written articles referring to foreign body inhalation over a 30 years period (1978–2008) was performed. The target of the analysis has been defined as the proportion of injuries as reported in the studies, stratified according to children demographic characteristics, type of FB, site of obstruction. The pooled proportions of FB were calculated using the DerSimonian and Laird approach.
Results: 1699 papers were retrieved and 1063 were judged pertinent; 214 English written case series were identified, among them 174 articles were available and have been included in the analysis. Airway foreign body most commonly occurs in young children, almost 20% of children who have inhaled foreign bodies being between 0 and 3 years of age. Organic FB, particularly nuts, are the most documented objects while, among inorganic FBs, the greatest pooled proportion has been recorded for magnets, which can be particularly destructive in each location. Non specific symptoms or a complete absence of symptoms are not unusual, justifying mistaken or delayed diagnosis. Acute and chronic complications seem to occur in almost 15% of patients.
Conclusions: Even if an enormous heterogeneity among primary studies seems to exist and even if the absence of variables standardized definitions across case series, including class age definition and symptoms and signs descriptions, seriously impairs studies comparability, our results testify the relevant morbidity associated with foreign body inhalation in children, stressing the importance of preventive measures.

1. Introduction

The inhalation/aspiration of foreign bodies (FB) into the upper airways can be a very serious event, sometimes resulting in fatal outcomes, and frequently having considerable social and economic consequences. Therefore, in scientific literature great attention has been devoted to this issue and several papers reporting single case description or detailing features of a case series have been published. Also several narrative reviews discussed more clinical

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doi:10.1016/j.ijporl.2012.02.004

aspects of the FB injuries, like clinical diagnosis and management of the injured child [1]. Very recently, some attempts have been made to start a systematic collection of FB in view of using them to characterize the risk of chocking in terms of size, shape and consistency of the FB [2]. However, most of the epidemiologic evidence on foreign bodies in children comes from single-center retrospective studies, without any systematic geographical and temporal coverage [3–7].

Particularly, in spite of the wide interest proven by the high number of published papers on the argument, no attempts have been made to synthesize the epidemiological data as arising from the literature. This paper is an attempt aimed at filling this gap, providing an estimate of the distribution of foreign body's injuries in children according to gender, age, type of FB, site of obstruction, clinical presentation, diagnostic/therapeutic procedures, complications, as emerging from a meta-analytic review of published papers.

2. Materials and methods

A free text search on PubMed database ((foreign bodies) OR (foreign body)) AND ((aspiration) OR (airways) OR (tracheobronchial) OR (nasal) OR (inhalation) OR (obstruction) OR (choking) OR (inhaled) OR (aspirations) OR (nose) OR (throat) OR (asphyxiation)) AND ((children) OR (child)) finalized to identify all articles referring to foreign body inhalation over a 30 yrs period (1978–2008) was performed.

Papers' pertinence was independently evaluated by two reviewers starting from title and abstract. Papers referring to adult FB injuries, other sites of injury other than aerial tract and iatrogenic causes were excluded. Only case series were included in the analysis while case reports were excluded. Papers referring to the same series of data were included only once in the meta-analysis. Only case series written in English were included.

For each record included in the analysis, information was extracted on country, period, children sex and age, FB type, site of obstruction, symptoms, signs, diagnostic and therapeutic procedures, delay at the diagnosis, complications, number of deaths.

The target of the analysis has been defined as the proportion of injuries as reported in the studies, stratified according to children demographic characteristics, injury dynamics, type of FB, site of obstruction. Moreover, also symptoms, signs, radiological findings, removal techniques, delayed or mistaken diagnosis, complications and death have been considered and pooled proportion computed.

The pooled proportions of FB was calculated using the DerSimonian and Laird approach [8,9]. All studies with missing values or zero counts were excluded pair wise from the analysis. First, a χ^2 test for homogeneity of proportions among the different studies was performed using the Cochran method 43. Thus, the pooled proportions of FB was estimated along with the corresponding 95% confidence intervals (CI), using again the DerSimonian-Laird random effects weighting scheme for the studies included in the analysis.

All analyses have been performed using the software R 44 [10] with the rmeta package [11].

3. Results

According with the search strategy previously described, 1699 papers were retrieved and 1063 were judged pertinent; 214 English written case series were identified, among them 174 articles were available and have been included in the analysis. Considered references are shown in Table 1. On the whole, articles' authors observed 30,477 children suspected of having aspirated a foreign body. Pooled estimates of injury proportion are presented in Tables 2–7 stratified for relevant variables including children and FB characteristics. For each stratum, the number of articles reporting data about the considered characteristic, the number of cases having the considered characteristic and the total number of cases described in the articles are reported. Particularly, in Table 2 injuries pooled proportions are presented stratified by children age and sex, and by injury dynamics (including adult presence and activity before accident); moreover, details regarding FB locations and FB types are presented respectively in Tables 3 and 4. In Table 5 pooled proportions of symptoms and signs are shown while in Table 6 radiographic findings and adopted removal techniques are described. Finally, in Table 7 pooled proportions of diagnostic delay, mistaken diagnosis, complication and deaths are reported.

4. Discussion

Taking stock of what is known in any field involves reviewing the existing literature, summarizing it in appropriate ways, and exploring the implications of heterogeneity of population and study for heterogeneity of study results. Meta-analysis provides a systematic way of performing this research synthesis, while indicating when more research is necessary. Usually, meta-analytic studies resume randomized controlled trials results, which are considered to provide the strongest evidence regarding an intervention. However, in many situations, including studies of risk factors, only data from observational studies are available and, even if the extreme diversity of study designs and populations in epidemiology could make the interpretation of simple summaries problematic, meta-analyses of observational studies continue to be one of the few methods for answering urgent questions in clinical and public health research.

Particularly, despite aspiration and inhalation of FBs are common events in paediatrics accounting for a not negligible proportion of accidental deaths in children under 4 years of age, this issue is still poorly understood and existing knowledge not yet systematically reviewed and synthesized.

Our study, in which 1063 were judged pertinent and only 174 English written case series were identified and included in the analysis, testifies that the great amount of papers about this topic are case reports typically consisting of complaints, examination findings, diagnosis, treatment and outcome; however, no hypothesis, data analysis or generalizable conclusion is possible on this base. On the other hand, the absence of variables standardized definitions across case series, including class age definition and symptoms and signs descriptions, seriously impairs studies comparability. Moreover an enormous heterogeneity among primary studies seems to exist. Despite these limitations, results obtained in the present study stress some key messages.

First of all, airway foreign body most commonly occurs in young children, almost 20% of children who have inhaled foreign bodies being between 0 and 3 years of age. Great attention is paid in scientific literature on objects causing the injury: organic FB, particularly nuts, are the most documented objects while, among inorganic FBs, the greatest pooled proportion has been recorded for magnets, which can be particularly destructive in each location. Moreover, injuries are frequently due to an incorrect manipulation of objects not conceived for children use, including pins, nails, screws, floats.

The clinical presentation of foreign body aspiration ranges from none to severe airway obstruction; cough, chocking, dyspnea, reduced/abnormal breath sounds and respiratory movements decreased appear as the most documented symptoms and signs; however, non specific symptoms or a complete absence of symptoms are not unusual, therefore, clinicians may fail to consider the diagnosis of an inhaled foreign body if child shows no symptoms at presentation, especially when also chest radiograph findings are normal. Even if chest radiograph findings

Table 1
References considered in the meta-analysis.

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Table 2
Injuries pooled proportions are presented stratified by demographic characteristics and injury dynamics. CI-lb: lower confidence interval bounds. CI-ub: upper confidence interval bounds. P values less than 0.05 indicate significant heterogeneity.

	Number of articles	Cases	Total number of cases (N)	Pooled-proportion	CI-lb	CI-ub	*p*-Value
Demographic characteristics							
Males	123	13,196	23,808	0.609	0.577	0.641	<0.001
Females	126	10,692	25,792	0.383	0.370	0.395	<0.001
Age 0–3	22	3240	4593	0.673	0.648	0.698	<0.001
Age > 3	30	2694	9495	0.254	0.216	0.292	<0.001
Injury dynamics							
Adult present	5	542	1044	0.563	0.279	0.846	<0.001
Child activity when injury occurred: playing	2	19	45	0.304	0.116	0.492	1.000
Child activity when injury occurred: eating	2	19	45	0.422	0.099	0.745	0.018

Table 3
Injuries pooled proportions are presented stratified by FB locations. CI-lb: lower confidence interval bounds. CI-ub: upper confidence interval bounds.

	Number of articles	Cases	Total number (N)	Pooled-proportion	CI-lb	CI-ub
Nose	21	1475	1918	0.835	0.810	0.859
Larynx	49	559	6872	0.213	0.197	0.228
Trachea	97	2458	16,923	0.157	0.147	0.168
Bronchus	113	18,366	21,164	0.882	0.871	0.893
Lung	14	407	3960	0.271	0.252	0.289
Right side	99	9788	0	0.629	0.613	0.646
Left side	96	7582	0	0.425	0.408	0.441

Table 4
Injuries pooled proportions are presented stratified by types of FB. CI-lb: lower confidence interval bounds. CI-ub: upper confidence interval bounds.

	Number of Articles	Cases	Total number (N)	Pooled-proportion	CI-lb	CI-ub
Organic FB						
Nuts	96	6504	18,536	0.395	0.340	0.450
Organic unspecified	55	5553	13,857	0.338	0.262	0.413
Seeds	64	3678	14,227	0.256	0.210	0.301
Unspecified food	24	421	3871	0.211	0.167	0.254
Weed/Wood	14	124	2633	0.136	0.093	0.180
Legumes	42	1406	11,058	0.107	0.084	0.131
Other food	21	266	2967	0.096	0.069	0.123
Grape	2	2	21	0.091	−0.032	0.213
Maize	14	119	2216	0.050	0.030	0.070
Bones	35	393	7417	0.049	0.037	0.060
Meat	10	112	1870	0.040	0.019	0.061
Coffee grain	5	58	1210	0.034	0.005	0.063
Carrots	14	153	4284	0.034	0.021	0.047
Popcorn	16	122	2926	0.032	0.018	0.046
Chicken	3	50	1580	0.024	0.008	0.040
Candy	6	59	2713	0.021	0.007	0.036
Apples	12	88	3920	0.020	0.013	0.027
Hotdog	6	72	2710	0.019	−0.001	0.039
Organic overall	172	19,113	29,881	0.558	0.549	0.567
Inorganic FB						
Magnet	3	13	90	0.341	−0.173	0.854
Sponge	5	42	264	0.146	0.044	0.249
Inorganic unspecified	69	2386	14,529	0.131	0.122	0.140
Other inorganic	36	751	6698	0.117	0.100	0.134
Foam	8	99	931	0.092	0.042	0.142
Battery	9	35	692	0.090	0.041	0.140
Toys	24	198	3031	0.081	0.059	0.103
Pen top	27	169	3569	0.080	0.051	0.110
Plastic pieces	54	629	8352	0.078	0.065	0.092
Pin nail tack screw	64	781	11,369	0.076	0.064	0.087
Paper	16	92	1498	0.061	0.038	0.083
Whistle	6	31	509	0.057	0.018	0.097
Button bead	19	264	3708	0.054	0.033	0.075
Coin	6	69	1560	0.050	0.021	0.080
Balls/balloon	21	87	2306	0.044	0.027	0.061
Cotton	4	18	497	0.029	0.008	0.051
Stones/shell	41	158	5210	0.027	0.020	0.035
Jewellery	12	31	1798	0.017	0.006	0.028
Pen/pencil	14	41	2933	0.011	0.006	0.015
Inorganic overall	172	5808	29,881	0.197	0.188	0.205

Table 5
Pooled proportions of symptoms and signs. CI-lb: lower confidence interval bounds. CI-ub: upper confidence interval bounds.

	Number of articles	Cases	Total number (N)	Pooled-proportion	CI-lb	CI-ub
Symptoms						
Cough	82	12,605	16,782	0.612	0.601	0.623
Choking	45	5947	11,680	0.468	0.353	0.583
Dyspnea	47	4507	9021	0.346	0.258	0.433
Throat pain	3	111	256	0.290	-0.035	0.614
Fever	53	1970	12,018	0.187	0.163	0.211
Toracic pain	9	43	661	0.140	0.121	0.160
Aspecific symptoms	11	147	1178	0.098	0.061	0.135
No symptoms	11	109	1327	0.079	0.046	0.111
Vomiting	11	96	1013	0.074	0.047	0.100
Voice hoarsenes	10	73	1178	0.048	0.024	0.073
Blood stained mucus	10	59	1875	0.021	0.010	0.031
Unconsciouness	3	15	1625	0.008	0.000	0.016
Signs						
Respiratory movements decreased	2	33	56	0.659	0.569	0.750
Decreased air entry	25	2672	4011	0.633	0.611	0.655
Decreased sounds	26	4262	8343	0.504	0.361	0.648
Abnormal breath sounds	78	5312	10,744	0.503	0.492	0.514
Tachypnea	15	2340	6723	0.476	0.451	0.501
Asimmetric auscultation	3	224	371	0.454	0.081	0.826
Acute Respiratory distress	10	986	3097	0.387	0.281	0.493
Nasal Flaring	5	94	395	0.340	0.189	0.491
Abnormal breath sounds wheezing	67	3152	7565	0.334	0.283	0.386
Nose pain	3	82	374	0.269	0.047	0.491
Abnormal breath sounds rhonchi	19	618	3271	0.204	0.151	0.257
Accessory muscles use	11	411	4193	0.196	0.147	0.244
Purulental discharge	8	232	1257	0.189	0.110	0.268

Table 5 (*Continued*)

	Number of articles	Cases	Total number (N)	Pooled-proportion	CI-lb	CI-ub
Abnormal breath sounds rales	9	412	2536	0.183	0.120	0.246
Abnormal breath sounds stridor	44	991	7147	0.177	0.149	0.205
Odor	4	52	312	0.150	0.056	0.243
Cyanosis	41	1258	9487	0.131	0.108	0.155
Abnormal breath sounds crackles	8	139	743	0.126	0.071	0.182
Nose bleeding	11	33	854	0.023	0.009	0.037
Subcutaneous emphysema	2	5	350	0.013	0.002	0.024

Table 6
Pooled proportions of radiographic findings and chosen removal techniques. CI-lb: lower confidence interval bounds. CI-ub: upper confidence interval bounds.

	Number of Articles	Cases	Total Number (N)	Pooled-Proportion	CI-lb	CI-ub
Radiographic findings						
Normal X-ray	75	5870	16,514	0.474	0.460	0.487
Rayradiopaque.FB	74	2525	16,155	0.246	0.234	0.259
Emphysema	76	5398	14,808	0.447	0.434	0.460
Atelectasis	63	2601	15,988	0.193	0.171	0.214
Pneumonia	59	1635	13,044	0.178	0.153	0.203
Pneumothorax/Pneumomediastinum	33	415	5425	0.078	0.064	0.093
Pleural effusion	7	166	2087	0.035	0.002	0.069
Number of performed X ray	98	18,236	18,446	0.990	0.984	0.995
Removal techniques						
Bronchoscopy/laryngoscopy	111	19,125	19,677	0.990	0.984	0.995
Forceps	13	600	1220	0.474	0.460	0.487
Positive pressure technique	3	25	192	0.246	0.234	0.259
Surgery/thoracotomy/bronchotomy	47	479	15,153	0.447	0.434	0.460

Table 7
Pooled proportions of diagnostic delay, mistaken diagnosis, complication and deaths. CI-lb: lower confidence interval bounds. CI-ub: upper confidence interval.

	Number of articles	Cases	Total number (N)	Pooled-proportion	CI-lb	CI-ub
Complications						
Other infection	7	152	1443	0.162	0.031	0.293
Pneumonia Broncopneumonia	25	397	3605	0.106	0.084	0.127
Bronchiectasis	13	83	3742	0.096	0.053	0.140
Actelectasis	10	99	2601	0.028	0.014	0.042
Larynx edema	15	229	7874	0.025	0.016	0.033
Respiratory arrest	15	93	2886	0.024	0.013	0.035
Cardiopulmunary arrest	19	434	9683	0.020	0.011	0.030
Tracheal laceration	7	82	6156	0.006	−0.001	0.013
Lung abscess empyema	6	14	1037	0.005	−0.003	0.012
Pneumothorax/pneumomediastinum	23	56	7002	0.004	0.002	0.006
Pulmonary edema	6	8	476	0.003	0.000	0.007
Complications Overall	54	1482	13,684	0.157	0.131	0.184
Mistaken diagnosis						
Asthma	5	54	1205	0.231	0.183	0.279
Infections	6	221	1273	0.307	0.257	0.356
Delay in diagnosis						
Up to 24 h	49	3427	7625	0.470	0.452	0.488
Greater than 24 h	51	8027	11,118	0.601	0.585	0.617
Deaths	127	718	31,305	0.062	0.056	0.068

compatible with an inhaled foreign body include air trapping, atelectasis, and pneumothorax, none of these findings are pathognomonic for foreign body inhalation and in our study almost half of cases had normal radiography, while definitive diagnosis is usually performed by endoscopic evaluation.

Diagnosis of an inhaled foreign body was delayed by more than 24 h in almost 40% of cases. As frequently reported in scientific literature, delayed diagnosis of an inhaled foreign body can result in serious acute and chronic complications which seem to occur in almost 15% of patients. Particularly, pneumonia and broncho-pneumonia seem to be the most frequently documented in analyzed case series.

Interestingly, while data regarding FB type are almost always reported, only a relatively small proportion of articles presents details regarding clinical presentation, diagnostic procedures and complications revealing poor attention toward the follow up of patients after FB extraction and thus toward long terms outcomes.

Finally, only 5 article reported data regarding adult presence during injury occurrence; this fact reveals the insufficient attention paid to preventive issues by both clinicians and parents while, on the contrary, given the considerable mortality and morbidity associated with foreign body inhalation in children, the importance of preventive measures needs to be emphasized to parents and caregivers.

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