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Systematic Review of Case Reports of Poor Neonatal Outcomes With Water Immersion During Labor and Birth

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ABSTRACT

Water immersion is a valuable comfort measure in labor, that can be used during the first or second stage of labor. Case reports of adverse outcomes create suspicion about water birth safety, which restricts the availability of water birth in the United States. The objective of this study was to synthesize the information from case reports of adverse water birth events to identify practices associated with these outcomes, and to identify patterns of negative outcomes. The research team conducted a systematic search for cases reports of poor neonatal outcomes with water immersion. Eligible manuscripts reported any adverse neonatal outcome with immersion during labor or birth; or excluded if no adverse outcome was reported or the birth reported was unattended. A qualitative narrative synthesis was conducted to identify patterns in the reports. There were 47 cases of adverse outcomes from 35 articles included in the analysis. There was a pattern of cases of *Pseudomonas* and *Legionella*, but other infections were uncommon. There were cases of unexplained neonatal hyponatremia following water birth that need further investigation to determine the mechanism that contributes to this complication. The synthesis was limited by reporting information of interest to pediatricians with little information about water birth immersion practices. These data did not support concerns of water aspiration or cord rupture, but did identify other potential risks. Water immersion guidelines need to address infection risk, optimal management of compromised water-born infants, and the potential association between immersion practice and hyponatremia.

Key Words: adverse neonatal outcome, obstetrical, water birth

Water immersion during childbirth is an essential care strategy that can be used in the first or second stage of labor to promote comfort and relaxation for pregnant people. Women who use water immersion report a greater ease of mobility, a stronger perception of safety, having a sense of empowerment, and a more positive birth experience.[1–3] Water immersion in labor and birth is associated with decreased perception of pain and decreased use of pharmacologic pain management including epidural anesthesia.[4] Use of water birth in the United States remains restricted because of concerns about safety. While the safety and effectiveness of water immersion during the first stage of labor is generally accepted, questions persist about safety during the second stage.[4]

Professional organizations are polarized in their support of water birth. The American College of Nurse Midwives (ACNM) and the American Association of Birth Centers[5] are in favor of water birth for the benefits of comfort and effective pain relief without any increased risk for healthy women. However, the American Congress of Obstetrics and Gynecologists and the American Academy of Pediatrics cite inconsistent research with maternal benefits, no recognized benefits to infants, and case reports of poor neonatal outcomes.[6]

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In the last 6 years, a number of meta-analyses and systematic reviews have been published to summarize maternal and neonatal outcomes of water birth. Three meta-analyses included 29 to 39 studies with greater than 30 000 water births evaluated.[7–9] One systematic review evaluated 7 randomized controlled trials, with 2615 water births.[10] Although this literature had limitations associated with variable methodology, heterogeneity, and few randomized controlled trials, neonatal outcomes of water birth or hydrotherapy in labor were equal and sometimes better to those for land births.[7–10] A cumulative meta-analysis demonstrated these findings to be stable over time.[9]

In this literature there was wide variation in the definitions of some outcomes, such as infection, resuscitation elements, or consistent measures of certain outcomes, such as perineal trauma. Additionally, there was significant variation in eligibility criteria, infection control practices, and management of complications. Few studies have compared the management of water immersion complications, such as shoulder dystocia or cord rupture.[7–11] There are gaps in research related to optimal provider education and clinical practice.

The purpose of this study was to conduct a systematic review and narrative synthesis of case reports of adverse neonatal outcomes with water immersion in the first and second stages of labor. This narrative synthesis of case reports was used to identify patterns of care or events that might diminish water birth safety. This exploration of adverse outcomes of water birth has value in that these uncommon incidents are frequently cited as exemplars that demonstrate water birth to be unsafe, despite case reports being the lowest form of evidence. The intent of this study was not to determine water birth safety, but rather to highlight commonalities that can be used to make water birth even safer.

METHODS

Eligibility criteria

The protocol for this systematic review was registered with Prospero: CRD42019127765. Articles were included in the synthesis if they reported at least one case of an adverse neonatal outcome with water immersion during labor or delivery. Eligibility was not based on terminology because the terminology used to describe the use of water in labor is varied. Water birth refers to a birth where the infant emerges entirely into water and is brought to the surface immediately to take their first breath. Water immersion in labor refers to having the laboring person submerged in water during the first stage of labor, but not necessarily the second stage of labor. Hydrotherapy in labor generally refers to water submersion in the first stage, but not the second stage.

Articles were excluded if they were descriptions of observational or experimental studies; if they were a duplicate publication of a case; if they discussed theoretical risks for water birth without presenting a specific case; if they were narrative accounts of a birth without adverse neonatal outcome; or if the text could not be translated easily into English by the research team.

Information sources

The following electronic databases were searched—Medline, Embase, Web of Science, and CINAHL—using variations of the key search words: water birth, water immersion, hydrotherapy, case, study, report, and review. The searches were conducted in English. Additionally, all references for studies included in systematic reviews or meta-analyses of water immersion for labor and birth were reviewed as well as the references of those articles included in the study for full-text review. As each new article was identified as eligible, its references were reviewed for additional potential articles.

Search strategy

The search terms used for PubMed were ("Case Reports" [Publication Type]) AND ((((waterbirth) OR "water birth")) OR ((Hydrotherapy) AND childbirth)). The search strategy for all databases is included in Supplement 1 (available at: http://links.lww.com/JPNN/A14).

Article and case selection process

The selection was based on a 2-step process. In the first round of selection, 2 reviewers independently assessed each article title and abstract for potential inclusion. If reviewers disagreed on an article, it was automatically included in the second round of selection. In the second round of selection, the same reviewers independently assessed each full-text article to determine whether it met inclusion and exclusion criteria. The list of excluded articles is listed in Supplement 2 (available at: http://links.lww.com/JPNN/A15).

If reviewers disagreed on the eligibility of an article, they discussed the article until they reached consensus. All cases of poor neonatal outcomes with water immersion that were presented within accepted manuscripts were included.

Data collection process

Data were collected using an abstraction tool purposefully designed to gather information about water immersion practices that may be associated with adverse outcomes. The abstraction tool was developed by the

research team after reviewing several cases and identifying what information each reviewer considered meaningful to the purpose of the study. Literature from the previous meta-analysis was used to inform the items on the abstraction tool.[7–11] The abstraction tool was pilot tested on 3 cases, and each reviewer conducted data collection with the tool independently. When the reviewers disagreed on a data element, they reviewed the case report together to reach consensus.

Data items

The data abstraction tool collected medical record elements such as the condition of the laboring person, location of delivery, Apgar scoring, presenting symptoms, timing of symptom onset, results of laboratory or imaging studies, final diagnosis, duration of illness, the presence of any obstetrical complications (such as meconium-stained fluid or maternal fever), and the outcome. In addition, the data collection tool included information about the process of water immersion including the condition of the tub, cleaning protocols, and any specific care practices reported such as duration of water immersion and removal of the infant from the water.

Risk of bias of individual studies

For this review, bias was conceptualized as lacking information necessary to understand how the adverse event occurred. The potential bias in information presented was assessed in terms of the completeness of 3 different areas: (1) the pregnancy, (2) the care provided during the birth, and (3) the condition of the infant. Completeness of information was operationalized as low, adequate, or high, where adequate represented enough information within the context of the article to understand what occurred.

Synthesis methods

The data were integrated using a qualitative narrative synthesis in 2 stages. In the first stage, details or aspects of the cases were classified to create categories that would facilitate comparison between the classifications. The categories included birth location, adverse event severity, immersion during birth or during labor only, and category of presenting symptom (respiratory or other), presence of infection, the professional discipline of the case author, and likely audience.

In the second stage of syntheses, the research team created a matrix of categories and outcomes to compare each case according to the details contained in each case. For example, some comparisons were hospital versus out-of-hospital birth, infants with respiratory illness versus nonrespiratory illness, and earlier cases versus later cases. These similarities and differences were examined and evaluated to identify overarching themes that inform safe practice related to water birth. The themes served as an organizing framework to report the results and make recommendations for clinical practice, provider education, and research. The process of synthesis was obtained from the method described by Thomas and Harden[12] as well as Cruzes et al.[13] The publication year, country of practice, and journal audience were evaluated to assess the extent to which the data represented the range of contemporary water immersion practices.

RESULTS

Article and case selection

After removing duplicates, 173 articles were available for screening. In the first round of review, 103 articles were excluded because they did not report on a specific case. The full-text review of the remaining 70 articles identified 35, which were excluded. The reasons for exclusion are included in Supplement 1 **(**available at: http://links.lww.com/JPNN/A14**)**, and were most often that no case of an adverse outcome was reported. The final sample included 35 articles that reported 48 cases of adverse neonatal events. A list of excluded articles is available in Supplement 1 (available at: http://links.lww.com/JPNN/A14).

Most of the cases originated from the United States or the United Kingdom, with 11 cases each. There were 2 cases each from the Netherlands, Australia, Germany, and Canada. There was 1 case each from Japan, New Zealand, Sweden, Belgium, and Italy. This sample included water immersion from a variety of maternity care health systems, suggesting the problems reported represent the broadest variety of adverse outcomes seen in practice. The PRISMA flow diagram is presented in Figure 1.

Fourteen reports, or slightly less than 50%, were published within the last 10 years and therefore highly likely to reflect current water immersion practice. Two clusters of publication were identified, 18 cases between 2000 and 2004 and 7 between 2009 and 2011. The clustering of case reports suggests the publication of these cases represents a reaction to something else in clinical water birth practice, such as a UK audit of water birth published in 1999[14] and a Cochrane Systematic Review of Water Immersion published in 2009,[15] rather than the natural distribution of adverse events with water immersion. This bias is further supported by the reporting of cord avulsion with no negative effect on the infant and reporting of cases of transient tachypnea of the newborn (TTN) as suspected water aspiration.

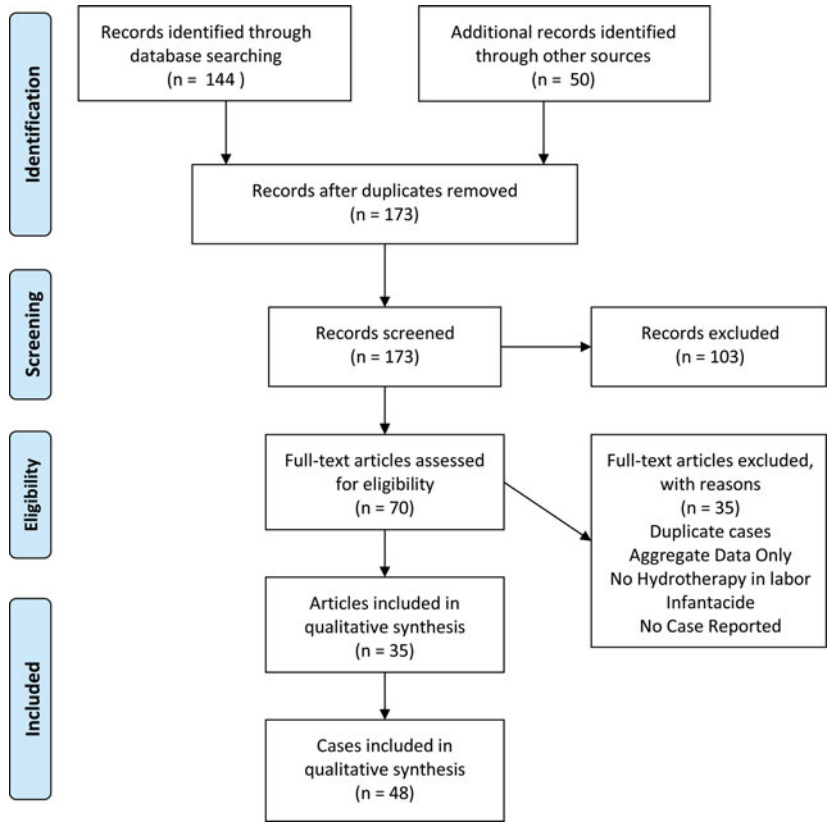

Figure 1. Study flow diagram. This figure is available in color online (www.jpnnjournal.com).

Case characteristics

The identified cases included both structured case reports for publication and cases briefly mentioned in letters to the editor. Respiratory difficulty was the presenting symptom in 24 cases (50%). Infection was the most common diagnosis, with 18 cases (37%). There were 11 cases of suspected water aspiration, and 8 cases of cord avulsion. There were 7 neonatal deaths. Five of the deaths were from sepsis, while the remaining 2 cases did not list a cause of death. Four cases did not report on the final condition of the infant. The timing of the cases was variable, with the onset of symptoms occurring immediately after birth in 17 cases, and 30 cases presenting within the first 24 hours of life. Information on the length of illness was missing for 22 cases, but 7 cases resolved within 24 hours. Eleven cases lasted between 2 and 6 days, and 8 cases lasted from 1 to 7 weeks. Full information about the cases is available in Table 2.

Risk of bias within studies

There were significant gaps in the information provided in the case reports. Few of the reports provided information about the pregnancy or the process of labor, preventing synthesis of eligibility criteria for water immersion in labor. When provided, pregnancy information was limited to a statement of an uneventful pregnancy and the gestational age at delivery. Most reports provided inadequate information about protocols followed for water immersion. The most commonly described protocols were maintenance of a particular temperature and immediate removal of the infant from the water after delivery. Most reports provided adequate information about the condition of the newborn, often describing Apgar scores, the presenting signs and symptoms, laboratory results, and the care provided. Results of the analysis of risk of bias in reporting can be seen in Table 1.

Synthesis of results

Twenty-one reports identified adverse outcomes for hospital births, 18 for home births, and 4 in freestanding birth centers. Five reports did not specify the birth location. Infection was the most common adverse outcome for both home and birth center deliveries. The

Table 1. **Characteristics of included articles**

Report	Lead author specialty	Cases	Country	Journal	Publication year	Information quality		
						Pregnancy information	Birth information	Infant information
1	Pediatrics	1	Canada	Pediatrics	2017	Moderate	Low	Adequate
2	Pediatrics	2	UK	Physicians	1997	None	None	Moderate
3	Generalist	3	UK	Physicians	1995	None	None	Low
4	Infectious disease	4	Canada	Physicians	2017	Moderate	Low	Adequate
5	Nursing	5-8	USA	Pediatrics	2003	Low	Low	Low
6	Pathology	9	Australia	Pathology	2010	Low	Moderate	Adequate
7	Midwifery	10-13	UK	Midwives	2002	Low	Moderate	Low
8	Pediatrics	14	Netherlands	Physicians	2000	Low	Low	Moderate
9	Radiology	15-16	UK	Physicians	2009	Low	Low	Moderate
10	Infectious disease	17	Italy	Infectious disease	2001	Adequate	Low	Adequate
11	Public health	18	USA	Midwives	2015	Low	Adequate	Moderate
12	Public health	19-20	USA	Public health	2017	Low	Low	Moderate
13	Pediatrics	21	USA	Pediatrics	1997	Low	Moderate	Adequate
14	Pediatrics	22	USA	Pediatrics	2019	Low	Low	Moderate
15	Obstetrics	23	Germany	Maternal health	2011	Adequate	Moderate	Adequate
16	Pediatrics	24	UK	Physicians	2005	Low	Adequate	Adequate
17	Pediatrics	25	USA	Pediatrics	2015	Low	Moderate	Adequate
18	Pediatrics	26	Netherlands	Physicians	2016	Low	Low	Adequate
19	Pediatrics	27	USA	Pediatrics	2006	Adequate	Low	Adequate
20	Pediatrics	28, 29	UK	Maternal health	2009	Moderate	Moderate	Adequate
21	Pediatrics	30	Japan	Infectious disease	2003	Low	Low	Low
22	Radiology	31-34	New Zealand	Pediatrics	2002	Low	Low	Moderate
23	Pediatrics	35	USA	Pediatrics	1997	None	None	Adequate
24	Public health	36	UK	Infectious disease	2014	Low	Moderate	Moderate
25	Pediatrics	37	UK	Physicians	1994	None	None	Adequate
26	Obstetrics	38	Sweden	Maternal health	1993	None	Moderate	Adequate
27	Pediatrics	39-40	UK	Physicians	1993	None	None	Low
28	Midwife	41	USA	Midwifery	2014	Moderate	Low	Low
29	Public health	42	Belgium	Infectious disease	2002	Low	Low	Moderate
30	Pediatrics	43	USA	Infectious disease	2013	Low	Adequate	Low
31	Pediatrics	44	UK	Maternal health	2010	Low	Adequate	Adequate
32	Midwifery	45	UK	Midwifery	2003	Low	Moderate	Low
33	Unclear	46	Germany	Physicians	2001	None	Low	Moderate
34	Obstetrics	47	Australia	Perinatology	2016	Low	Low	Adequate
35	Pediatrics	48	USA	Pediatrics	2006	Low	Adequate	Adequate

Table 2. **Characteristics of included cases**

Case	Delivery location	Respiratory symptoms?	Timing of symptoms	Illness severity	Illness duration	Final diagnosis	Outcome
1	Birth center	No	<1 wk	Severe	6 d	HSV sepsis	Death
2	Home	No	<4 d	Severe	4 wk	Polycythemia	Discharge
3	Not stated	Yes	Not stated	Severe	Not stated	Hyponatremia	Discharge
4	Home	No	>1 wk	Severe	5 wk	*Legionella* pneumonia	Discharge
5	Home	No	<24 h	Severe	Not stated	Respiratory distress syndrome	Discharge
6	Home	Not stated	Unclear	Moderate	Not stated	Probable water intoxication	Discharge
7	Hospital	Not stated	<1 wk	Unclear	Not stated	Shone's complex	Not reported
8	Hospital	Not states	<1 wk	Unclear	Not stated	Group B streptococcal meningitis	Not reported
9	Home	Yes	Immediate	Severe	4 d	*Pseudomonas* sepsis	Death
10	Hospital	No	Immediate	None	None	Cord rupture	Discharge
11	Hospital	No	Immediate	None	N/A	Cord rupture	Discharge
12	Hospital	No	Immediate	None	N/A	Cord rupture	Discharge
13	Hospital	No	Immediate	Moderate	3 d	Cord rupture	Discharge
14	Home	Yes	Immediate	Severe	<24 h	Anemia due to cord rupture	Unclear
15	Not stated	Yes	<24 h	Severe	Not stated	PPHN	Discharge
16	Not stated	Yes	<24 h	Severe	Not stated	PPHN	Discharge
17	Hospital	Yes	<1 wk	Severe	7 wk	*Legionella* pneumonia	Discharge
18	Home	Yes	<1 wk	Severe	19 d	*Legionella* pneumonia	Death
19	Home	Yes	<24 h	Moderate	Not stated	Congenital heart disease	Discharge
20	Home	No	<1 wk	Moderate	10 d	*Legionella* pneumonia	Discharge
21	Home	Yes	Immediate	Severe	5 d	Aspiration pneumonitis	Discharge
22	Home	Yes	<24 h	Severe	Not stated	Sepsis	Discharge
23	Hospital	No	Immediate	Severe	<6 h	Cord avulsion	Discharge
24	Hospital	Yes	Immediate	Mild	<48 h	Water aspiration	Discharge
25	Home	Yes	<24 h	Moderate	<24 h	*Haemophilus* parainfluenza sepsis	Discharge
26	Home	Yes	<24 h	Mild	3 d	Water aspiration	Discharge
27	Birth center	Yes	< 24 h	Severe	Not stated	*Pseudomonas* sepsis	Discharge
28	Not stated	Yes	<24 h	Mild	Not stated	Water aspiration	Discharge
29	Hospital	Yes	<24 h	Mild	Not stated	Water aspiration	Discharge
30	Home	No	<1 wk	Mild	8 d	*Legionella* pneumonia	Death
31	Hospital	Yes	<24 h	Severe	5 d	Hypoxic-ischemic encephalopathy	Discharge
32	Hospital	Yes	<24 h	Moderate	<24 h	Water aspiration	Discharge
33	Hospital	Yes	Immediate	Moderate	<24 h	Water aspiration	Discharge
34	Hospital	Yes	Immediate	Moderate	<24 h	Water aspiration	Discharge
35	Birth center	No	>1 wk	Moderate	14 d	*Pseudomonas* bacteremia	Discharge
36	Home	Yes	<1 wk	Severe	Not stated	*Legionella* pneumonia	Not reported
37	Hospital	No	<24 h	Mild	4 d	*Pseudomonas* colonization	Discharge
38	Home	No	Immediate	Severe	Not stated	Unclear	Death
39[a]	Hospital	No	Immediate	Severe	15 h	Not reported	Death

(*continues*)

Table 2. **Characteristics of included cases (*Continued*)**

Case	Delivery location	Respiratory symptoms?	Timing of symptoms	Illness severity	Illness duration	Final diagnosis	Outcome
40[a]	Hospital	No	Immediate	Severe	Not stated	Hypoxic-ischemic encephalopathy	Discharge
41	Birth center	No	Immediate	Healthy	None	Cord rupture	Discharge
42	Hospital	No	>1 wk	Severe	Not stated	*Legionella* pneumonia	Discharge
43	Home	No	<24 h	Severe	15 d	Disseminated adenovirus infection	Death
44	Hospital	Yes	<24 h	Severe	<3 d	Water aspiration	Discharge
45	Not stated	No	Immediate	None	None	Cord rupture	Discharge
46[a]	Hospital	No	>1 wk	Severe	Not stated	*Pseudomonas* meningitis	Discharge
47	Hospital	Yes	Immediate	Severe	<6 d	Water aspiration	Discharge
48	Home	Yes	<24 h		4 d	Water aspiration	Discharge

Abbreviations: HSV, Herpes simplex virus; PPHN, persistent pulmonary hypertension.
[a]Hydrotherapy was used for labor only, delivery occurred in the conventional manner.

most common adverse outcome for hospital birth was suspected water aspiration.

Eleven of the reported cases described either no long-term adverse effects to the infant or a mild, transient condition. Twenty-five reports described an infant condition categorized as severe based on the need for respiratory support, 12 of these included a diagnosis of infection. Of the 7 cases that reported death of the infant, 5 were the result of an infection; 2 *Legionella pneumophila*, 1 *Pseudomonas aeruginosa*, 1 human alphaherpesvirus, and 1 *human adenovirus* (cases 1, 9, 18, 30, and 45).

Five of the cases reported adverse events from water immersion for labor only. Four of the 5 cases presented concerns about potential risks of laboring in warm water. The fifth article reported on a case of *Pseudomonas* meningitis. For all of the other reports, the use of hydrotherapy included labor and birth in the water.

In 24 of the cases, the presenting symptoms were respiratory changes. Of these, 9 reported an infection diagnosis while 10 reported a diagnosis of suspected water aspiration. Cases that reported nonrespiratory presenting symptoms included a variety of diagnoses including cord avulsion, infection, polycythemia, and hypoxic-ischemic encephalopathy (Appendix).

PATTERNS IDENTIFIED

Pattern 1: Be aware of waterborne pathogens

There were 3 identified groups of infection cases. The first group included reports of pathogens known to be transmitted without water, including human herpesvirus, human adenovirus, *Haemophilus parainfluenzae,* Group B streptococcal meningitis, and 1 unknown pathogen (cases 1, 8, 21, 22, 25, and 43). The authors of these cases raised a concern that being in water increased risk of transmission or exacerbated the process of infection. The evidence does not support this assumption for 2 reasons. First, no pathogen was reported more than once, which would be expected if water increased transmission of any particular virus or bacteria. Second, 4 of the cases included information that suggests other more likely methods of transmission. Two cases reported history and symptoms that suggested vertical transmission during pregnancy rather than intrapartum transmission (cases 25 and 43), including maternal illness during the final week of pregnancy and a poorly responding infant at delivery[16] and 1 case included a potentially contaminated medical device (case 21). For the final case, the umbilical cord was not severed but left intact with the placenta for longer than 24 hours (case 22). The conclusion that there is no evidence for increased transmission of

infection with hydrotherapy is consistent with 3 meta-analyses that found no increased risk of infections with water immersion.[7,8,10,11]

The second group included reports of infections with waterborne bacteria (cases 4, 9, 17, 18, 20, 27, 30, 35, 36, 37, 42, and 46), including *Legionella pneumoniae* and *P. aeruginosa*. Six of these occurred after home birth, 2 after birth center birth, and 4 following hospital birth. These specific organisms are not commonly associated with sepsis in land-born infants, where *Streptococcus agalactiae (GBS), Listeria monocytogenes*, and *Haemophilus influenzae* are much more prevalent.[17] Knowledge of this pattern of infection is important information for pediatricians who will evaluate water-born infants who have become ill so that the appropriate evaluation and treatment of these specific infections can be implemented without delays.

The authors of these cases present a concern that these infections are transmitted due to water aspiration. The cases of *P. aeruginosa* infection included reports of sepsis and meningitis but not pneumonia, suggesting water aspiration was an unlikely route of transmission. In contrast, all cases of infection with *L. pneumophila* reported a form of pneumonia, which is consistent with known patterns of transmission through aerosolized droplets. It is unlikely that infants born into water contaminated with *L. pneumophila* are more likely to aspirate the water than infants born into water contaminated with *P. aeruginosa*. An alternative likely explanation is the transmission of *L. pneumophila* occurs via aerosolized droplets from running jets or other splashing of water after the infant is brought to the surface.

The final group included cases whose authors reported a diagnosis of suspected infection, which later presented negative cultures. These were transitioned to a diagnosis of suspected water aspiration (cases 16, 26, 28, 29, 31, 32, 33, 46, and 49). In 7 of the 9 resolved cases, symptoms resolved quickly within 24 hours. When these cases were compared to confirmed infections that presented in the first 24 hours (cases 9, 19, 21, 22, 25, 27, and 37) there is a notable difference in the progressive deterioration reported. Cases that resolved had normal laboratory values throughout the illness except for a rising C-reactive protein.

It is notable that, despite the lack of positive cultures, only one author indicated antibiotics were discontinued at 48 hours (case 46). In other reports of resolved conditions, the authors suggest treatment continued for 7 days despite repeated negative cultures and the infants stable on room air since day 2 or earlier. Current recommendations for the management of sepsis in term newborns are to discontinue antibiotics in the presence of negative cultures and a well infant.[18] Based on the information provided by authors in these cases, discontinuing antibiotics when cultures are negative may prevent unnecessarily extended hospitalizations and limit unnecessary exposure to antibiotics.

Pattern 2: Water aspiration is not a common causative factor

Eleven cases reported the neonatal condition was suspected to be due to water aspiration. In 7 of the reports, the description of the condition and recovery meets the diagnostic criteria for TTN and the diagnosis of suspected water aspiration appears to have been given in place of a diagnosis of TTN. The incidence of TTN is 5.7 per 1000 births in term deliveries (37-42 weeks), and current evidence does not support an increased incidence of any respiratory distress for infants born in water.[7,8,10,11]

Five of the cases classified as TTN did not meet the diagnostic criteria for TTN. Case 6 presented with seizures and hyponatremia at 8 hours without mention of respiratory symptoms. Case 21 exhibited grunting from delivery, was treated with 3 doses of surfactant, and required ventilation for 5 days. This case was considered aspiration pneumonitis because a small amount of *Burkholderia pickettii* was identified on culture of the tracheal aspirate after 3 days of ventilation. Case 44 exhibited respiratory compromise at 2.5 hours, with respiratory acidosis, hypothermia, and the presence of blood-stained endotracheal and nasogastric aspirates. Case 47 was born in poor condition, needed ventilation, experienced elevated prothrombin time, partial thromboplastin time, and international normalized ratio with hyponatremia. Although the information reported on each case was limited, the newborn condition in each of these cases does not appear related to a common physiologic mechanism. There does not seem to be enough evidence to demonstrate aspiration as a common pathway to illness.

Case 48 is the only case with information consistent with aspiration of water; the author reports the infant was dropped in the water after birth and remained underwater for an undisclosed time. In this case, the infant began showing signs of respiratory distress and oxygen saturation at 85% to 90% approximately 2.5 hours after delivery and required continuous positive airway pressure with F_{IO_2} of 100% to maintain oxygen saturation of 90% until at least 12 hours after birth. This was not a poor outcome resulting from the water birth itself but rather a departure from established safe practice guidelines that recommend bringing the infant directly out of the water and not allowing the face to be resubmerged.[19]

Pattern 3: Cord rupture can be identified and managed

Eight reports of cord rupture were identified. Only one report (case 14) described clinical data consistent with cord avulsion after the birth. This was not recognized until the volume of blood lost was sufficient to cause changes in skin color and respiratory rate. The publication of this case in the early 2000s resulted in the public discussion of cord rupture in scholarly literature, which may have informed practice change to immediately confirm intact cord with water immersion deliveries and is included in the ACNM recommendations of evidence-based practice for water birth.[20] Five of these reports (cases 10, 11, 12, 41, and 45), all published after 2000, had no accompanying sequelae for the newborn because of rapid identification and clamping of the cord. Two of the reports (cases 13 and 23) presented clinical data that suggested the rupture occurred prior to the birth. These were identified and managed immediately, with no sequelae to the infant. Instances of cord rupture before the birth have been identified in the research literature previously.[21] Based on the cases available for review, birth in water does not appear to prevent identification of a cord rupture, as 7 of the 8 cases identified and managed the rupture immediately.

Pattern 4: Birth attendants must practice according to guidelines

There were 8 cases in which the water birth practice was not consistent with recommended guidelines or otherwise suggested the birth attendant was untrained. Case 6 was a birth into the home bathtub rather than a birth tub. Case 9 reported birth during water immersion despite thick meconium, generally a contraindication for water delivery. Case 16 was a water birth despite ruptured membranes for more than 24 hours and maternal fever during labor. Case 21 was birth in a home hot tub rather than a tub designed for water immersion during labor and birth. Case 31 was an accidental birth in water for a person only intending to labor in water. Case 36 reported birth into a rented tub that was filled and kept warm 2 weeks prior to the beginning of labor.[22] In cases 9 and 21, the reported Apgar scores do not match the reported condition of the infant at birth, suggesting a lack of knowledge of assigning Apgar scores or the provider's artificial inflation of the Apgar score to give the appearance of a healthy newborn.

Case 38 was the publication of a third hand report that suggested the death was due to water aspiration; however, further investigation into the case revealed this information was contradicted by the autopsy. This case was categorized with other cases of incomplete training because the author reports the birth attendants did not travel with appropriate resuscitation equipment to the mother's home.[23] Case 48 reported the infant was dropped in the water after cutting the cord, and that the infant remained in the water for an undisclosed amount of time. This is the only case in which aspiration of water was confirmed, but details of the case confirmed the there was a serious breach in safe care.

Pattern 5: Be aware of potential for hyponatremia

Three of the cases reported neonatal hyponatremia as part of the condition (cases 3, 6, and 49). While the authors of these reports suspected hyponatremia due to water aspiration, none of these cases included any signs of respiratory compromise in addition to the documented hyponatremia. Alternatively, the problem of neonatal hyponatremia in the first 8 hours may be due to maternal hyponatremia from overhydration with oral or parenteral fluids.[24]

Hemodilution during labor has been reported in women who consume large volumes of water during labor, and water immersion does result in hemodilution under some conditions.[25–27] Early studies on hemodynamics of water immersion did not find a difference in serum sodium levels during immersion.[28,29] However, these studies were limited to 60 minutes or less of immersion and did not include hydration of the participant, which creates a different water immersion condition than some women may experience in water immersion for labor and birth. This raises the possibility that women whose labors are longer than average, and who choose to drink water for hydration, may experience hemodilution. This uncommon condition represents a gap in knowledge about water birth, where more research is needed to identify whether these cases represent an association with water immersion or are rare, random events unrelated to water immersion.

Risk of bias across studies

Most of the cases were documented by physicians, reporting in medical journals with a general audience (10 cases) or in journals for pediatric specialists (10 cases). The articles were most often written by pediatric specialists, with the data reported focused on pediatric concerns. The next most common audience was infectious disease or public health professionals (6), followed by midwives (4). Most of the case report literature reviewed addressed conditions and treatment strategies of the newborn; the sample was missing important information about water immersion practice, maternal condition, or details of the labor process that would shed light on the cause and inform protocol revisions.

DISCUSSION

Summary of evidence

This review synthesized the reports of adverse neonatal outcomes with water immersion during labor and delivery. There were 5 patterns of practice identified from the review that will support improvement in guidelines, education, and research: suspect waterborne pathogens in infants with sepsis, water aspiration is not a common causative factor for adverse events, cord rupture is manageable, birth attendants must practice according to guidelines, and consider the potential for hemodilution for neonates with hyponatremia.

Based on this review, *Legionella* and *Pseudomonas* infections appear to be the most likely adverse events associated with contemporary practice of water immersion during delivery, though future research is needed to determine whether these infections are more common with water immersion. Water immersion protocols need to include strategies to verify and maintain a clean water supply, appropriate tubs for water birth, as well as the cleaning of all equipment used during water immersion. Cases of *Legionella* and *Pseudomonas* were more common in out-of-hospital births, possibly because hospitals have policies in place to maintain clean water supply. Awareness of these 2 pathogens may be significant for pediatricians caring for water-born infants, particularly if this was also an out-of-hospital birth. Lack of awareness of the organisms or misinformation about the location of birth can cause delays in appropriate treatment.

In this review of case reports, neonatal aspiration of the pool water does not appear to be a common cause of the conditions reported. This finding is important for pediatric specialists who must make clinical decisions based on presenting symptoms in relation to the events of the birth. Although few cases provided enough information about pregnancy and birth to assess practice conditions, 8 studies provided information that indicated the birth attendant was not following safe practice guidelines for birth with water immersion. This finding ought to be interpreted with caution, because these cases represent care provided over nearly 30 years and practice guidance has changed over that time. The earliest clinical guidance provided basic eligibility criteria (term, singleton, and cephalic) and guidance to maintain the temperature of the water.[30] Over time, guidance has progressed to include care practices such as the use of intermittent monitoring and recommendations for handling emergencies such as shoulder dystocia.[31,32] Additionally, more recent guidelines provide detailed recommendations on which conditions should exclude a pregnant person from laboring in water.[19,30,31]

These cases highlight the importance of birth attendants receiving appropriate training prior to providing care for water immersion. Provider adherence to best practice guidelines must be monitored and reviewed periodically as a part of quality surveillance. While the evidence for best practice with water immersion is still developing, general recommendations must include the need to monitor the temperature of the water, bringing the infant to the surface as quickly as possible while avoiding excessive tension on the cord, checking promptly for cord avulsion after infant emerges, and using a birth tub deep enough to facilitate movement and emergency maneuvers, should these become necessary.[6]

This review found that when cord rupture occurred, identification and management was achieved quickly in all but the first reported case.[33,34] During a water birth, when the baby is brought up from the water onto the mother's chest, this maneuver may place undue tension on the cord and increase the risk of avulsion. Practice guidelines for water birth safety must address this issue specifically, by bringing the infant out of the water, which will facilitate an evaluation of the cord before placing the infant on the mother's chest. Since 2016, a joint statement between the American Association of Birth Centers, American College of Nurse-Midwives, Midwives Alliance of North America, and National Association of Certified Professional Midwives includes this recommendation.[6]

Finally, this review identified the need to better understand how water immersion and hydration practices in labor interact to affect the risk for maternal hemodilution, contributing possibly to neonatal hyponatremia. If labor predisposes to hyponatremia and immersion predisposes to natriuresis, it is important to understand the conditions that increase or decrease the interactive effects.[24–27] Because neonatal hyponatremia is likely related to maternal hyponatremia, understanding what relationship exists is essential for understanding the best practices for managing water immersion during labor and birth.[26] This is an area where research is needed to explore associations between maternal hemodilution and (1) duration of maternal immersion and (2) methods of maternal hydration during labor and birth in water. Additionally, it is crucial for pediatric providers to recognize this vulnerability in water-born infants, so neonates with symptoms can be evaluated promptly and effectively.

Limitations

These data were limited by the criteria that articles must present a case of adverse neonatal outcomes with water immersion. While this allowed the identification of

patterns in the cases, this analysis cannot provide information about the overall rate of adverse outcomes with water immersion.

CONCLUSION

This study highlights several areas where water birth guidelines could be strengthened. Guidelines need to address prevention, identification, and treatment of infections due to *L. pneumophila* and *P. aeruginosa* in the water supply, and consideration of these pathogens in those infants who develop infections. More research is needed to develop practice guidelines for infants with mild respiratory difficulty to determine optimal processes for evaluation and determination of possible water aspiration and to distinguish this from mild, self-resolving TTN. Guidelines need to address the immediate assessment of the umbilical cord once the infant is born. Quality monitoring of provider practice is crucial to determine that guidelines for care are being observed. Future research focused on maternal hydration with water immersion can determine what, if any, role water immersion plays in increasing risks for hyponatremia.

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Appendix. List of Included Articles

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