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Heated birthing pools as a source of Legionnaires' disease

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SUMMARY

In June 2014 Public Health England confirmed a case of Legionnaires' disease (LD) in a neonate following birth at home in a hired birthing pool incorporating a heater and a recirculation pump which had been filled in advance of labour. The case triggered a public health investigation and a microbiological survey of an additional ten heated birthing pools hired or recently hired to the general public across England. The birthing pool used by the parent of the confirmed case was identified as the source of the neonate's infection following detection of *Legionella pneumophila* ST48 in both patient and environmental samples. *Legionella* species were detected by quantitative polymerase chain reaction but not culture in a further three pools together with other opportunistic pathogens identified by culture and matrix-assisted laser desorption ionization–time of flight (MALDI–ToF) mass spectrometry. A Patient Safety Alert from NHS England and Public Health England was issued stating that heated birthing pools filled in advance of labour should not be used for home births. This recommendation remains in place. This investigation in conjunction with other recent reports has highlighted a lack of awareness regarding the microbiological safety of heated birthing pools and their potential to be a source of LD and other opportunistic infections. Furthermore, the investigation raised important considerations with regards to microbiological sampling and testing in such incidents. Public health authorities and clinicians should consider LD in the differential diagnosis of severe respiratory infection in neonates within 14 days of a water birth.

Key words: Laboratory tests, *Legionella*, Legionnaires' disease, opportunist infections, water (quality).

INTRODUCTION

Legionellae are causative agents of legionellosis, which includes Legionnaires' disease (LD), a potentially fatal pneumonia, and Pontiac Fever, a self-limiting illness [1]. Legionellae are ubiquitous in the environment but proliferate favourably in water systems operating between 20 °C and 45 °C. Infection typically follows the inhalation of legionellae-containing aerosols or the aspiration of legionellae-contaminated water.

The true incidence of *Legionella* infections within the population is not known but is underestimated

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as legionellae are not traditionally considered and therefore not tested for, as causative agents of pneumonia. This is particularly true in infants as *Legionella* infections occur more commonly in individuals aged ⩾50 years. In Europe between 2009 and 2012 <0·5% of all reported European cases of LD were in persons aged <19 years [2].

Home birthing pools have been used in the UK since the 1980s and remain a popular aid during child birth, with 8% of women using a birthing pool for labour in 2013 [3]. Two types of pool are predominantly in use. The majority of births are in pools filled at the time of labour; however, some births occurs in pools that are filled up to 2 weeks prior to labour and that incorporate both a heater and recirculation pump [4].

There are four reports of neonatal legionellosis associated with birthing pools, two in hospitals [5, 6] and two in domestic settings [7, 8]. Home birthing pools had not been considered a source for legionellosis in Europe due to an absence of reported cases so no specific national or international guidance existed on the management of this risk. The incident initially documented [8] and described here in greater detail is the first recorded case of neonatal legionellosis associated with a heated birthing pool used in the home setting in Europe and is the only case associated with a birthing pool where molecular techniques were used to establish an epidemiological link between patient and the environmental source. Results of the first reported microbiological survey of heated birthing pools, incorporating a heater and a recirculation pump filled in advance of labour are discussed.

CASE REPORT

In June 2014, Public Health England (PHE) was notified of a case of LD in a neonate with onset of symptoms 3 days after a home birth in a heated birthing pool (index pool), that had been filled 2 weeks before labour [9]. The pool incorporated a heater and recirculation pump. *Legionella pneumophila* serogroup 1 (sg1) was isolated by culture from a bronchoalveolar lavage. Genotyping of the isolate was conducted by the Respiratory and Vaccine Preventable Bacteria Reference Unit (RVPBRU), PHE Colindale. Using the M13 modification of the European Working Group for *Legionella* Infections (EWGLI) standard sequence-based typing (SBT) method [10] the isolate was characterized as sequence type (ST) 48 (allelic profile 5,2,22,27,6,10,12) monoclonal antibody subgroup Bellingham. The rapidity of the onset of illness effectively excluded any other reasonable exposure, particularly when considered alongside previously published evidence [5, 6, 8]. The birthing pool was assumed to be the likely source of infection and aspiration the likely mechanism whereby infection occurred.

Environmental investigation

The pool had been drained and disassembled prior to the arrival of Environmental Health officials so it was not possible to obtain any pool water samples. The pool was reassembled and a small amount of residual water from the impellor pump as well as organic debris from an inlet pipe was collected. Surface swabs were taken in an attempt to sample biofilm, from the pool cover, liner, coarse filter housing, small recirculation pipe, circulation pump inlet pipe and the ends of the flexible hose used to fill the pool in accordance with recognized *Legionella* sampling guidance, BS 7592:2008. Some of these surfaces were dry. Samples were analysed by the PHE Food, Water and Environmental Microbiology (FW&E) laboratories using a method based on ISO 11 731 and by a recently validated (ISO TS 12 869:2012) quantitative polymerase chain reaction (qPCR) method for *Legionella* species, *L. pneumophila* and *L. pneumophila* sg1 [11]. The majority of samples were heavily contaminated with other microorganisms preventing isolation of *Legionella* by culture. Quantitative PCR testing revealed four samples to be *L. pneumophila* sg1 positive. The swab from the inside pool covers yielded the highest concentration of detected *Legionella* sg1 DNA by qPCR (Table 1). *L. pneumophila* sg1 positive samples were also obtained from the small recirculation pipe, the pool liner and the debris recovered from a pipe at lower concentrations of detected DNA (Table 1). DNA extracts from these four environmental swab samples were forwarded to RVPBRU. Testing using a novel rapid qPCR for the detection of *L. pneumophila* and *L. pneumophila* sg1 DNA [12] followed by a combination of both nested and direct SBT methodology on qPCR-positive DNA samples as described by the ESGLI (formerly EWGLI) protocols [13] was performed on the four positive environmental DNA extracts. A full SBT profile of ST48 (5,2,22,27,6,10,12) was obtained from a single qPCR-positive environmental sample and partial profiles were obtained from three other qPCR-positive samples (Table 1) which confirmed

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Table 1. *Microbiological test results of the heated birthing pools studied in this survey*

Pool	Supplier	Samples	*Legionella* culture (c.f.u.)	*Legionella* PCR (GU)	Other microbiological results
Index	A	Residual water	<2/ml	<100/ml	
		Debris deposit	<20/item	5×10^2/item *L. pneumophila* sg1	
		Filter housing	<400/item	<4000/item	
		Inside pool covers swab	<20/swab	$1{\cdot}5 \times 10^5$/swab *L. pneumophila* sg1	*L. pneumophila* sg1 ST48 identified by SBT
		Pool liner swab	<20/swab	$2{\cdot}1 \times 10^3$/swab *L. pneumophila* sg1	*E. meningoseptica* identified by MALDI–ToF
		Circulation pump swab	<20/swab	$2{\cdot}3 \times 10^4$/swab *L. pneumophila* sg1	
1	B	1 water	<20/l	<200/l	n.t.
2	C	1 water	<20/l	$2{\cdot}3 \times 10^2$/l *Legionella* species	ACC, coliforms, *E. coli*, Enterobacteriaceae, *P. aeruginosa, S. aureus* satisfactory
		2 swabs	<20/swab	<200/swab	
3	A	7 swabs	<20/swab	<200/swab	Coliforms, *E. coli, P. aeruginosa* and *S. aureus* satisfactory
4	A	8 swabs	<20/swab	<200/swab	n.t.
5	B	10 swabs	<20/swab	1 swab $9{\cdot}4 \times 10^3$/swab *Legionella* species 1 swab $2{\cdot}8 \times 10^2$/swab *Legionella* species	$4{\cdot}9 \times 10^5$ MPN/swab Enterobacteriaceae $8{\cdot}9 \times 10^2$ MPN/swab Enterobacteriaceae All other swabs <100 MPN/swab. *E. coli* and *S. aureus* satisfactory. *A. xylosoxidans, C. gilardii, E. cloacae* and *S. maltophilia* identified by MALDI–ToF in both swabs
6	D	1 water	<20/l	$2{\cdot}2 \times 10^3$/l *Legionella* species	*C. pauculus* and *P. aeruginosa* identified by MALDI–ToF
7	B	2 water	<20/l	<200/l	ACC satisfactory
8	B	1 water	<20/l	n.t.	n.t.
9	B	1 water	<20/l	n.t.	n.t.
10	B	2 water	<20/l	n.t.	n.t.

ACC, Aerobic colony count; c.f.u., colony-forming units; GU, genome units; MALDI–ToF, matrix-assisted laser desorption ionization–time of flight; MPN, most probable number; n.t., not tested; PCR, polymerase chain reaction; SBT, sequence-based typing.

the presence of *L. pneumophila* sg1 ST48 in the birthing pool. *Elizabethkingia meningoseptica*, an opportunistic pathogen that can cause infections in infants [14] was identified by culture and matrix-assisted laser desorption ionization–time of flight (MALDI–ToF) as the major contaminant [9]. The domestic water supply was negative for *Legionella* by both culture and qPCR.

Public health intervention and investigation

Following establishment of an epidemiological link between patient and birthing pool the National Health Service (NHS) in conjunction with PHE issued a Patient Safety Alert [15] stating heated birthing pools (incorporating both a re-circulation pump and heater) filled in advance of labour, should not be used for labour or birth, in the home setting. This information was circulated to suppliers of heated birthing pools and to local government authorities.

To gain a better understanding of the risk posed by this type of birthing pool, 10 additional heated pools, filled in advance of labour (from four suppliers, including the supplier of the index pool) and hired by the general public at the time were sampled for *Legionella* and other indicator organisms including aerobic colony counts, coliforms, *Pseudomonas aeruginosa* and Enterobacteriaceae according to international standards. All pools were sampled during a 9-day period following notification of the index case. Eight of these pools were in a domestic residence and two had been returned to a supplier and cleaned prior to sampling. Where possible, 1-l water samples were obtained from filled pools. If this was not possible swab samples of biofilm were collected. Samples were analysed in PHE FW&E laboratories in London, Porton, Preston and York. The range of microbiological tests performed on each pool varied depending on the laboratory that performed the tests and the tests requested by the submitting local authority. A standardized set of tests would have been preferred but was not possible in the time-frame of the investigation. All birthing pools were tested for *Legionella* species by culture; however, none were found to be culture positive (Table 1). Six of the 10 pools were tested by qPCR for *Legionella* species. Where positive, they were then specifically tested by qPCR for *L. pneumophila* and *L. pneumophila* sg1 by the aforementioned method. Three of the pools (nos. 2, 5 and 6) were positive for *Legionella* species (non-*L. pneumophila*) by qPCR (Table 1). For pools 5 and 6 the *Legionella* selective culture plates were overgrown with other microorganisms, possibly explaining why *Legionella* was not detected by culture methods and only by qPCR. Contaminating flora were subcultured and identified by MALDI–ToF mass spectrometry as *Achromobacter xylosoxidans, Cupriavidus gilardii, Enterobacter cloacae* and *Stenotrophomonas maltophilia* for pool 5 and *Cupriavidus pauculus* and *P. aeruginosa* for pool 6. All are potentially opportunistic pathogens linked to infections in infants [16–20]. Two swabs from pool 5 tested positive for Enterobacteriaceae. The results of other tests performed on the pools were satisfactory from a water microbiology perspective (Table 1).

DISCUSSION

The results of the first reported survey of heated birthing pools, filled in advance of labour in the home setting, reinforce significant concerns as to the microbiological safety of such devices and are indicative of an industry-wide problem. The detection of *Legionella* and other opportunistic pathogens suggest that these devices provide optimal conditions for microbial growth and that recommended disinfection may not be suitable. All of the pools discussed in this report were in essence modified recreational spa pools, incorporating both a heater and re-circulation pump. Similar devices were implicated in cases of neonatal LD in both the USA [6] and Japan [7]. This type of pool can be complicated in structural design compared to other birthing pools which comprise a rigid or inflatable vessel that is filled with water during labour. Heated birthing pools can contain complex pipework, creating a large surface area that can promote microbial colonization and be difficult to decontaminate. Supplier recommendations are to fill these pools up to 2 weeks in advance of labour and to circulate warm water (between 26 °C and 40 °C) until birth. Debris and detritus can enter the pool if not covered. Use of the pool by other family members is encouraged, representing a mechanism whereby organic and microbial load could be introduced to the pool.

The disinfection instructions and products issued by the four pool suppliers were reviewed and several concerns raised. For all suppliers, instructions, while complex in methodology were limited in detail and assumed a degree of existing user knowledge. The biocide regimen for suppliers A, B and C involved the addition of several products to the pool at particular intervals, dependent on use, together with a

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requirement to measure pH, or oxygenation or chlorine/bromine concentrations and to clean the filters 1–3 times per week. These instructions rely on good user compliance which cannot be guaranteed in the domestic setting. There were no instructions as to what action to take should the pH, oxygenation or biocide levels fall outside stated parameters. Three of the four suppliers (A, B and C) included a chlorine-based disinfectant but the suggested frequency of use differed. Supplier A (index pool) advised that the chlorine-based disinfectant be added at the time of filling and then fortnightly thereafter. It is unlikely that the recommended 2 ppm free-chlorine would have been maintained for the entire 2-week period and if the pool pump was not operating circulation of the biocide through the pipework and filters would not have occurred. A coagulant/oxidizing agent combination was also supplied with the index pool with recommendations to use daily and additionally 1 h before use. The purpose of these products was to improve water clarity. According to available Material Safety Data Sheets (MSDS) the coagulant product was incompatible with oxidizing agents but it was recommended that both be added simultaneously. For two suppliers a weekly dose of chlorine biocide was advised. For supplier B a weekly chlorine treatment was stated as optional and a weekly sodium carbonate-based cleaning treatment was also advised. The efficacy of such a treatment in this setting is not known. For supplier C a weekly active oxygen-chlorine combination treatment was advised. For supplier D a halogen-free active oxygen-based system was supplied consisting of a liquid activator and separate active oxygen granules. For all suppliers there were no instructions to monitor biocide levels between treatments, to adjust biocide levels after heavy use or what action to take should any of the treatments be missed. There was no correlation between biocide regimen and detection of *Legionella* or other pathogens.

Two pools (nos. 3 and 4) that had been returned to supplier A and cleaned were included in this survey. All of the microbiological tests performed on these pools were considered to be satisfactory suggesting that the cleaning protocols used were suitably robust. Examination of these cleaning procedures, and the cleaning procedures of other suppliers confirmed this opinion (although clean pools from other suppliers were not tested) and reinforced the opinion that the major risk is generated at the point of use. The lack of an appropriate and detailed biocide regimen reinforced the opinion that these devices were unsafe for domestic use due to the potential for growth of pathogenic microorganisms. Consequently, on 30 June 2014, PHE recommended that heated birthing pools (incorporating both a recirculation pump and heater), filled in advance of labour, should not be used for labour or birth in the home setting.

The public health investigation and survey of domestic birthing pools has raised important considerations with regards to microbiological sampling and testing in such incidents. While culture of the swabs from the index pool did not yield any *Legionella*, the qPCR analysis was positive. This was also observed for three of the additional survey pools. The traditional method of sampling for *Legionella* is to take water samples or swabs for biofilm, typically from wet surfaces. Dry swabs may not necessarily be considered by public health investigators. We therefore recommend that in future cases where water samples or wet surfaces are not available that swabs from dry surfaces be taken. The usefulness of *Legionella* qPCR during public health investigations has also been highlighted. Culture samples failed to yield *Legionella*. Microbial overgrowth on culture media was observed in the index case samples and two of the additional pools. Results from qPCR were obtained in 5 h, several days ahead of possible culture results. The lack of culture positives due to heavy contamination often precludes isolation of *Legionella* reducing the ability to link patient isolates to an environmental source. Molecular detection has previously been used to rapidly detect sources in other cases of *Legionella* [21]. Similarly in this case, the use of rapid SBT directly on the DNA extracts from four environmental swab samples resulted in concurrent results with the patient's isolate and the birthing pool. This reinforces that use of rapid SBT on urgent cases and suspected clusters/outbreaks of LD can produce valuable results on qPCR-positive samples wherein the isolation of *L. pneumophila* is not possible [22]. In the recently reported case in Texas [7] where culture failed to yield any *Legionella* isolates, PCR was not used as a detection method and definitive confirmation of source was not achieved although its merits were discussed by the authors.

Standard qPCR will not distinguish between viable and non-viable cells so it was not possible to determine if the positive qPCR results from environmental samples occurred due to the presence of viable *Legionella*. Definitive isolation of *Legionella* using culture is always of benefit in case/cluster/outbreak

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analysis. However, molecular-based results can be imperative. While qPCR detection of non-viable cells may lead to false positives [23] a multi-method approach (culture with qPCR and other molecular techniques such as direct SBT) can enhance the detection of *Legionella* and provide public health professionals with a rapid indication as to potential sources of infection. This is the only case of LD associated with a birthing pool to report a molecular epidemiological link between patient and the environmental source and this would not have been possible without the use of qPCR.

CONCLUSION

This particular type of birthing pool had not been highlighted as a potential source of microbiological risk to public health officials or any regulatory body with powers to assess the safety of such devices in England. The legal responsibility for providing a safe birthing pool in England rests with the supplier. It was clear from the available evidence that none of the suppliers had considered the microbiological issues in relation to heated birthing pools including the likelihood of growth of *Legionella* or the safety and efficacy of recommended disinfection regimens.

This investigation has significantly added to the evidence base in relation to the microbiological safety of heated birthing pools filled in advance of labour. Nonetheless, birthing pools filled at the time of labour may also be a risk for contamination by *Legionella* [5, 24]. The case described here combined with previous cases in Italy, Japan and the USA indicate neonatal legionellosis following a water birth in the home or hospital setting can be a risk when sufficient water controls are not in place [5, 6, 9, 25]. Increased awareness regarding the risks posed by either type of device is required. Home water births are increasingly popular in Europe and enhanced surveillance and improved detection methods may reveal more cases of LD and other opportunistic infections. Clinicians should remain aware of *Legionella* and other opportunistic infections as potential threats to infants following a water birth. Authorities should consider whether or not heated birthing pools should fall within the definition of a medical device or healthcare product and thus be regulated in a similar manner. PHE's recommendation not to use heated birthing pools filled in advance of labour in the home setting remains in place. Currently there are only voluntary undertakings by suppliers not to hire out these devices.

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DECLARATION OF INTEREST

None.

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