Introduction

Outbreaks and pseudo-outbreaks associated with bronchoscopic procedures have been reported in the literature [1-3]. The microorganisms most commonly implicated in these outbreaks are Pseudomonas aeruginosa [4-8], Mycobacterium tuberculosis [9,10], and M. chelonae [11,12]. In most cases, only a single microorganism is identified, infection by several microorganisms is less frequent [13,14]. Contamination in past outbreaks had various causes, including water from automated endoscope reprocessors [11,15], damaged [7] or defect bronchoscopes [6,13,16], misuse of connectors, deficiencies in the cleaning process and, much less frequently, contamination of suction valves [17,18]. To reduce the risk of nosocomial infections from bronchoscopic procedures, national bronchoscopy guidelines have been established in several countries, including France [19-24]. Despite the increasing experience of bronchoscopic teams, up-to-date guidelines and outbreak reports, patients might still be exposed to contaminated bronchoscopes.

In April 2014, we were alerted to two cases of early-onset pneumonia with P. aeruginosa and Stenotrophomonas maltophilia in young and immunocompetent trauma patients, after exposure to the same bronchoscope in Edouard Herriot Hospital (Hospices Civils de Lyon, Lyon, France). Here, we report the results of this outbreak investigation and the impact of control measures.
Methods

Setting
Edouard Herriot Hospital is a 900-bed university-affiliated hospital from Hospices Civils de Lyon in Lyon, France, with four intensive care units (ICUs) accounting for 62 beds overall (ICUs #A, #B, #C and #D). Each year, more than 350 bronchoscopic and 2,000 cleaning procedures are performed in the hospital. In 2014, eight bronchoscopes were used in the endoscopy suite: three of the same model from manufacturer A (bronchoscopes A2, A2, A3) and five from manufacturer B (bronchoscopes B1, B2, B3, B4, B5). These bronchoscopes were deployed in ICUs, operating rooms or other care units.

Bronchoscope cleaning procedures
Bronchoscope cleaning and storage are centralised in ICU #C. Immediately after use, external bronchoscope surfaces are wiped with compresses and channels flushed with water. The bronchoscopes are taken to ICU #C for cleaning, as soon as possible, by authorised personnel, in accordance with a standardised local protocol adapted from French national recommendations [22]. A tightness test is performed before the bronchoscopes are soaked in detergent-disinfectant (Phagoclean NH4, Laboratoire Phagogène, Christeyns, France) and cleaned manually by wiping the outer surface, brushing and flushing internal channels. Each removable component is removed and cleaned. After rinsing, the bronchoscopes are processed in an automated endoscope reprocessor (Soluscope Series 3 PA, Soluscope, Aubagne, France) with disinfectant (Soluscope P), additive (Soluscope A) and detergent (Soluscope C+). Finally, after drying, the bronchoscopes are kept in an aseptic storage cabinet (Medi 72, Medinorme, La Seyne-sur-Mer, France). Standardised forms are completed for each procedure to maintain traceability.

Outbreak investigations
In April 2014, two cases of early-onset pneumonia with *P. aeruginosa*/*S. maltophilia* in young, not immunocompromised trauma patients in ICU #C were reported to the Infection Control Unit. These patients were exposed to the same bronchoscope (A1). An investigation was launched. In June 2014, two further pulmonary *P. aeruginosa*/*S. maltophilia* co-infections in patients exposed to bronchoscope A2 were encountered in ICU #B. An additional investigation was conducted with a retrospective cohort of patients exposed to bronchoscopes from 1 December 2013 to 17 June 2014 in Edouard Herriot Hospital and a nested case–control study.

Cases were defined as patients exposed to bronchoscopes between 1 December 2013 and 17 June 2014, with *P. aeruginosa*/*S. maltophilia*-positive cultures isolated from clinical respiratory samples. We included only positive cultures from broncho-alveolar lavage, tracheobronchial aspiration or plugged telescoping catheter (Combicath), obtained during or after the bronchoscopic procedure. Sputum samples were not considered. Controls were defined as patients exposed to bronchoscopes in the same period but without positive respiratory sample cultures of the microorganisms found on bronchoscopes, namely *P. aeruginosa*, *S. maltophilia*, *Klebsiella pneumoniae*, *Enterobacter cloacae* or *Achromobacter xylosoxidans*. For the epidemic curve, the period of interest began on 1 November 2013.

Patients exposed to bronchoscopes were identified from standardised, prospectively collected forms detailing bronchoscope use. Clinical sample results were obtained from the microbiological laboratory (according to European guidelines [25]) for patients exposed to bronchoscope for whom a microbiological sample was available, and medical case records were reviewed. Bronchoscope cleaning processes were audited by the Infection Control Unit. Prospective surveillance was implemented starting from the first investigation, as soon as the infection control team was informed. Every day, a member of the infection control unit was looking for new cases, checking results of cultures isolated from respiratory samples from patients in Edouard Herriot Hospital.

Environmental investigation
According to French guidelines [24], samples from suspected bronchoscope channels were taken by two authorised personnel, after cleaning and at least six
hours of storage. Sixty mL of Pharmacopeia dilution solution with antimicrobial inactivators (DNP buffer, AES Chemunex, bioMérieux, Marcy l’Etoile, France) were flushed into proximal ports and collected in sterile cups at the distal end of the operating channel. As the first set of cultures from bronchoscope channel samples were negative, bronchoscope suction valves and biopsy valves from suspected bronoscopes were sampled. In addition, surface samples from the aseptic storage cabinet for bronchoscopes, water samples from automated endoscope reprocessors and tap water samples from ICU #C were cultured.

In the nested case–control study, all exposures to bronchoscopes were considered to be potential risks. Other potential risk factors were unit, patient age, sex and number of bronchoscopic procedures per patient. To identify characteristics linked with the risk of being a case, categorical variables were compared by chi-square test, and continuous variables by the Mann-Whitney U test. All tests were two-tailed. A p value of <0.05 was considered significant. Univariate and multivariate logistic regression was undertaken with Stata 11.0 software (StataCorp, College Station, US).

**Molecular typing**

Macrorestriction profiles of total DNA from clinical and environmental isolates were acquired by pulsed-field gel electrophoresis (PFGE) on a CHEF-DR III unit (Bio-Rad, Hercules, United States (US)) [26]. Dral and XbaI served as restriction enzymes for *P. aeruginosa* and *S. maltophilia*, respectively. We ensured that the gels were comparable by including *Staphylococcus aureus* NCTC 8325 (with SmaI as restriction enzyme) as a reference, and PFGE patterns were analysed visually.

**Statistical analysis**

In the nested case–control study, all exposures to bronchoscopes were considered to be potential risks. Other potential risk factors were unit, patient age, sex and number of bronchoscopic procedures per patient. To identify characteristics linked with the risk of being a case, categorical variables were compared by chi-square test, and continuous variables by the Mann-Whitney U test. All tests were two-tailed. A p value of <0.05 was considered significant. Univariate and multivariate logistic regression was undertaken with Stata 11.0 software (StataCorp, College Station, US).
Results
Between 1 December 2013 and 17 June 2014, 157 patients were exposed to at least one bronchoscope, and 216 bronchoscopic procedures were undertaken. Median age was 62 years (interquartile range (IQR): 49–73 years), and 111 patients (71%) were male. Overall, 10 patients had P. aeruginosa/S. maltophilia-positive cultures isolated from respiratory sampling; 35 patients had at least one respiratory sample with P. aeruginosa, S. maltophilia, K. pneumonia, E. cloacae or A. xylosoxidans, but did not fulfil the criteria of the case definition, and the respiratory samples of 112 patients were negative for all of these pathogens. The 10 cases identified were all men, with a median age of 52 years (IQR: 23–67 years) (Table 1), three were previously hospitalised and nine were intubated during their ICU stay. Among them, two patients had secondary pneumonia, nine and 11 days after bronchoscopy.

Three cases died during ICU stay and their deaths were not related to bronchoscope contamination. Eight cases were associated with bronchoscope A1 and two cases with bronchoscope A2. During the outbreak, the attack rate among cases exposed to bronchoscopes was 9.4% between February and June 2014 compared with 0% between December 2013 and January 2014 (p<0.05); five patients had P. aeruginosa/S. maltophilia positive respiratory samples but had not been exposed to a bronchoscope (Figure 1).

We compared exposed patients co-infected with P. aeruginosa and S. maltophilia (n = 10) to non-infected patients (n = 112) during the outbreak period (Table 2). Univariate analysis disclosed that exposure to bronchoscope A1 or A2, hospitalisation unit and number of bronchoscopic procedures per patient were associated with increased risk of being a case. After multivariate...
### Table 1

Demographic and clinical characteristics of patients with pulmonary *Pseudomonas aeruginosa* and *Stenotrophomonas maltophilia* co-infection exposed to bronchoscopes, France, November 2013–August 2014 (n=10)

<table>
<thead>
<tr>
<th>Patient</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group (years)</td>
<td>40-49&lt;sup&gt;a&lt;/sup&gt;</td>
<td>70-79</td>
<td>50-59</td>
<td>30-39</td>
<td>18-29</td>
<td>18-29</td>
<td>50-59</td>
<td>18-29</td>
<td>60-69</td>
<td>70-79</td>
</tr>
<tr>
<td>ICU</td>
<td>ICU #A</td>
<td>ICU #B</td>
<td>ICU #A</td>
<td>ICU #C</td>
<td>ICU #C</td>
<td>ICU #C</td>
<td>ICU #A</td>
<td>ICU #C</td>
<td>ICU #B</td>
<td>ICU #B</td>
</tr>
<tr>
<td>Cause of hospital admission</td>
<td>Pneumonia</td>
<td>Respiratory distress syndrome, coma</td>
<td>Fever and aplasia after autologous transplantation</td>
<td>Abdominal wound</td>
<td>Polytrauma, coma</td>
<td>Septic shock, pneumonia, waiting for lung transplant</td>
<td>Polytrauma</td>
<td>Cardiac arrest</td>
<td>Multiple organ failure (post-operative)</td>
<td></td>
</tr>
<tr>
<td>Immunosuppression</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Death (cause of death)</td>
<td>No</td>
<td>No</td>
<td>Yes&lt;sup&gt;b&lt;/sup&gt;</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes&lt;sup&gt;b&lt;/sup&gt;</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Time between hospitalisation and bronchoscopic procedure (days)</td>
<td>6</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>10</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Bronchoscope exposure</td>
<td>A1</td>
<td>A1</td>
<td>A1</td>
<td>A1</td>
<td>A1</td>
<td>A1</td>
<td>A1</td>
<td>A1</td>
<td>A2</td>
<td>A2</td>
</tr>
<tr>
<td>Microbiology results</td>
<td><em>P. aeruginosa</em>, <em>S. maltophilia</em></td>
<td><em>P. aeruginosa</em>, <em>S. maltophilia</em>, <em>E. coli</em>, <em>C. tropicalis</em></td>
<td><em>P. aeruginosa</em>, <em>S. maltophilia</em>, influenza A virus</td>
<td><em>P. aeruginosa</em>, <em>S. maltophilia</em></td>
<td><em>P. aeruginosa</em>, <em>S. maltophilia</em>, <em>S. aureus</em></td>
<td><em>P. aeruginosa</em>, <em>S. maltophilia</em>, <em>E. cloacae</em>, <em>K. pneumoniae</em>, <em>C. albicans</em></td>
<td><em>P. aeruginosa</em>, <em>S. maltophilia</em></td>
<td><em>P. aeruginosa</em>, <em>S. maltophilia</em>, <em>A. xylosoxidans</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary pneumonia</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

ICU: intensive care unit; M: male; A1: bronchoscope A1; A2: bronchoscope A2.

<sup>a</sup> To anonymise the description of cases, the age is reported by stratum.

<sup>b</sup> Unrelated to bronchoscopic procedure.
Endoscopic and environmental cultures

As soon as the first two cases with P. aeruginosa/S. maltophilia in patients exposed to bronchoscope A1 were reported, the device was investigated and taken out of service. However, exposure to bronchoscope A2 was independently associated with heightened risk of P. aeruginosa/S. maltophilia co-infection (adjusted odds ratio (aOR) = 45.8, 95% confidence interval (CI): 8.4–248.7) compared with the absence of exposure to this particular endoscope.

In June 2014, two additional P. aeruginosa/S. maltophilia pneumonia cases were reported in patients exposed to bronchoscope A2 in ICU #B; it was removed from use. Channel and biopsy valve samples were negative, but the suction valve grew P. aeruginosa and S. maltophilia. Sampling was extended to bronchoscope A3, but channel and valve cultures were negative. Routine samples from the endoscopes of other

### Table 2
Factors associated with the risk of Pseudomonas aeruginosa and Stenotrophomonas maltophilia co-infection, France, November 2013–August 2014 (n=122)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Pa/Sm co-infection (n, %)</th>
<th>Non-infected (n, %)</th>
<th>p</th>
<th>Crude odds ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>10 (80)</td>
<td>95 (85)</td>
<td>0.006</td>
<td>1.0 (reference)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>52 (23–67)</td>
<td>62 (49–72)</td>
<td>0.07</td>
<td>45.8 (8.4–248.7)</td>
</tr>
<tr>
<td>Sex (female)</td>
<td>0 (0)</td>
<td>39 (35)</td>
<td>0.02</td>
<td>NE</td>
</tr>
<tr>
<td>Bronchoscope exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bronchoscope A1</td>
<td>8 (80)</td>
<td>9 (8)</td>
<td>&lt;0.001</td>
<td>45.8 (8.4–248.7)</td>
</tr>
<tr>
<td>Bronchoscope A2</td>
<td>4 (40)</td>
<td>16 (14)</td>
<td>0.03</td>
<td>4.0 (1.02–15.8)</td>
</tr>
<tr>
<td>Bronchoscope A3</td>
<td>2 (20)</td>
<td>17 (15)</td>
<td>0.69</td>
<td>1.4 (0.3–7.2)</td>
</tr>
<tr>
<td>Bronchoscope B1</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>NA</td>
<td>NE</td>
</tr>
<tr>
<td>Bronchoscope B2</td>
<td>1 (10)</td>
<td>24 (21)</td>
<td>0.39</td>
<td>0.4 (0.05–3.4)</td>
</tr>
<tr>
<td>Bronchoscope B3</td>
<td>2 (20)</td>
<td>25 (22)</td>
<td>0.86</td>
<td>0.9 (0.2–4.4)</td>
</tr>
<tr>
<td>Bronchoscope B4</td>
<td>0 (0)</td>
<td>27 (24)</td>
<td>0.08</td>
<td>NE</td>
</tr>
<tr>
<td>Bronchoscope B5</td>
<td>0 (0)</td>
<td>13 (12)</td>
<td>0.25</td>
<td>NE</td>
</tr>
<tr>
<td>Unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intensive care unit</td>
<td>10 (100)</td>
<td>70 (62)</td>
<td>0.02</td>
<td>NE</td>
</tr>
<tr>
<td>Operating rooms</td>
<td>0 (0)</td>
<td>30 (27)</td>
<td>0.06</td>
<td>NE</td>
</tr>
<tr>
<td>Other units</td>
<td>0 (0)</td>
<td>12 (11)</td>
<td>0.28</td>
<td>NE</td>
</tr>
<tr>
<td>Number of bronchoscopic procedures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5 (50)</td>
<td>95 (85)</td>
<td>0.006</td>
<td>1.0 (reference)</td>
</tr>
<tr>
<td>≥ 2</td>
<td>5 (50)</td>
<td>17 (15)</td>
<td>5.6</td>
<td>1.5–21.4</td>
</tr>
</tbody>
</table>

NA: not applicable; NE: could not be estimated; Pa/Sm: Pseudomonas aeruginosa/Stenotrophomonas maltophilia.

* Patients for whom Pseudomonas aeruginosa, Stenotrophomonas maltophilia, Klebsiella pneumonia, Enterobacter cloacae or Achromobacter xylosoxidans could not be isolated from respiratory samples.

* Median interquartile range.

* For one year older.

* More than one exposure was possible.

* Compared with the absence of exposure to this particular endoscope.
brands were all negative for *P. aeruginosa* or *S. maltophilia* during the outbreak period.

**Molecular typing**

PFGE revealed that isolates of *P. aeruginosa* (Figures 2 and 3) from clinical samples (patients C, D, E, F, G, H, I and J) were identical to isolates from channels and suction valve of bronchoscope A1 and to isolates from the suction valve of bronchoscope A2, but differed from isolates obtained from tap water in the disinfection room. Similarly, *S. maltophilia* isolates from clinical samples (except for patient I) were identical to isolates from the suction valve of bronchoscope A2 and to isolates from the channels of bronchoscope A1, but differed from tap water isolates found in the nurses’ station. Clinical isolates from patients A and B could not be recovered for typing.

**Bronchoscope cleaning processes**

Bronchoscope cleaning processes were audited by the Infection Control Unit with a standardised form. Some deficiencies were detected such as delays between endoscopy and cleaning. Moreover, the tightness test was not always performed before manual cleaning. However, these deficiencies were not specific to bronchoscopes from manufacturer A. Corrective actions were taken. Protocols were updated, traceability was improved, and single-use bronchoscopes were provided during the night and on-call duties in order to avoid latency between bronchoscopy and cleaning. As of 24 June 2016, no contamination of bronchoscope with *P. aeruginosa/S. maltophilia* has been identified, no new case related to bronchoscope exposure has occurred since bronchoscope disinfection was improved.

**Discussion**

From December 2013 to June 2014, an outbreak of *P. aeruginosa/S. maltophilia* co-infections was investigated in 10 patients undergoing bronchoscopy. These cases were related to two bronchoscopes of the same model from which *P. aeruginosa/S. maltophilia* were isolated from the suction valves. Clinical and contaminated bronchoscope isolates showed similar PFGE patterns. Two secondary pneumonia infections were identified among the cases. The respiratory samples may have been contaminated in the eight other cases, but antibiotic therapy was initiated for all patients and may have prevented the development of nosocomial pneumonia.

One of the key issues is to know how bronchoscope A1 was contaminated. As environmental sources of contamination were excluded, it may have been tainted during a bronchoscopic procedure on a patient colonised or infected by *P. aeruginosa/S. maltophilia*. Persistent contamination was probably partially due to defective bronchoscope cleaning as some deficiencies were highlighted by the audit. Furthermore, the complexity of suction valve cleaning and disinfection compared to other bronchoscopes might have contributed to the event.

Detection of this outbreak may have been further delayed because there was no specific surveillance of patients exposed to bronchoscopes. Moreover, the source of contamination was found by extended bronchoscope sampling. Bronchoscope disinfection is routinely assessed by channel sampling, as recommended in French guidelines [24]. The first results of bronchoscope contamination detection were probably false negatives. This outbreak highlights the benefits of routinely testing suction valves to look for bacterial contamination of bronchoscopes. In case of suspected contamination, suction valves should be systematically tested. If contaminated, they should be removed and replaced or sterilised. This outbreak raises questions about the cleaning process for suction valves.

Faced with the contamination of two bronchoscopes of the same model, within the same part (suction valves), we wonder about increased risks posed by these devices. We therefore reported the event to the French National Agency for Medicines and Health Products Safety (Agence nationale de sécurité du médicament et des produits de santé (ANSM)), where no other notifications concerning these bronchoscopes were filed. Disparities in the hospital’s stock of bronchoscopes regarding brands or preventive maintenance and lack of preventive maintenance were probable contributing factors. The two bronchoscopes under investigation were bought in 2007 and 2008 and did not have preventive maintenance contracts with the manufacturer.

Other outbreaks or pseudo-outbreaks tied to suction valve contamination have been described, mostly before the 2000s, but they involved mycobacteriae [17,18]. Bronchoscope contamination by *P. aeruginosa/S. maltophilia* was reported in the investigation of a pseudo-outbreak in Baltimore, US in 2008 [27] and more recently, contamination by *S. maltophilia* was reported in the Netherlands [28].

Our investigations had some limitations. We did not find the index case, and the route of pathogen transmission from bronchoscopes A1 and A2 was not clearly identified. Transmission may have occurred through one secondary case exposed to both bronchoscopes, or perhaps through the connectors. Moreover, *B. cepacia*, *E. cloacae* and *K. pneumoniae* were identified on one bronchoscope suction valve. Our case definition did not include patients with respiratory samples positive
for these microorganisms. We may have underestimated the magnitude of the outbreak.

**Conclusion**

We investigated an outbreak of *P. aeruginosa/S. maltophilia* pulmonary infections caused by suction valve contamination of two bronchoscopes from the same manufacturer. While bronchoscope contamination might be attributed to deficiencies in bronchoscope cleaning processes, suction valves of these bronchoscopes have a particular design which may increase the risk of contamination; the manufacturer was informed in the process and they were cooperative. No further confirmed cases exposed to bronchoscope have been detected as at 24 June 2016. Our findings underscore the need to test not only bronchoscope channels but also suction valves regularly for routine detection of bacteria. The large number of patients worldwide who are exposed daily to bronchoscope examinations highlights the necessity for regular updates of guidelines, appropriate hygiene procedures and reporting new risks to improve patient safety.

**Acknowledgements**

We thank the staff of the intensive care units of Edouard Herriot Hospital (Lyon, France) for their valuable cooperation. We thank François Vandenesch for his valuable assistance in microbiological analysis.

**Conflict of interest**

None declared.

**Authors' contributions**

Philippe Vanhems: project leader, performed epidemiological investigations, reviewed the manuscript. Marine Guy: performed epidemiological investigations, analysis and interpretation of results, manuscript writing. Philippe Vanhems: project leader, performed epidemiological investigations, reviewed the manuscript. Monique Hulin: performed environmental microbiologic analysis, reviewed the manuscript. Anne Regard: performed epidemiological investigations, reviewed the manuscript. Laurent Argaud: participated in epidemiological investigations, reviewed the manuscript. Bernard Floccard: performed pulsed-field gel electrophoresis analysis, reviewed the manuscript. Olivier Dauwalder: performed microbiologic analysis, reviewed the manuscript. Xavier Bertrand: performed pulsed-field gel electrophoresis analysis, reviewed the manuscript. Jullien Crozon-Clauzel: participated in epidemiological investigation, reviewed the manuscript. Bernard Floccard: participated in epidemiological investigation, reviewed the manuscript. Laurent Argaud: participated in epidemiological investigation, reviewed the manuscript. Michel Perraud: performed epidemiological investigations, reviewed the manuscript. Thomas Bénet: project leader, performed epidemiological investigations, analysis and interpretation of results, manuscript writing.

**References**


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