

## *Mycobacterium chimaera* – a new threat for cardiac surgical patients?

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### Abstract

An outbreak of invasive *Mycobacterium chimaera* infections associated with “heater-cooler” devices in patients treated with cardiac surgery has been described worldwide. The authors summarize the current state of knowledge regarding the epidemiology, diagnostics, treatment, and prevention of *Mycobacterium chimaera* infections in patients after cardiothoracic surgery.

**Key words:** *Mycobacterium chimaera*, cardiac surgery, surgical site infections.

### Streszczenie

W piśmiennictwie opisuje się kolejne przypadki występowania zakażeń o etiologii *Mycobacterium chimaera* związanych ze stosowaniem jednostek typu heater-cooler u pacjentów leczonych kardiologicznie. W związku z wykrywaniem infekcji w kolejnych krajach coraz powszechniej mówi się o epidemii. W niniejszym opracowaniu autorzy starają się podsumować obecny stan wiedzy dotyczący epidemiologii, diagnostyki, leczenia i profilaktyki zakażeń o etiologii *M. chimaera* u chorych leczonych kardiologicznie.

**Słowa kluczowe:** *Mycobacterium chimaera*, kardiologia, zakażenia miejsca operowanego.

In 2016, the US Food and Drug Administration (FDA) published recommendations on the use of heater-cooler units (HCUs) with regard to the risk of *Mycobacterium chimaera* infections in cardiac surgical patients [1]. Similar actions are being taken by other institutions due to the rising incidence of atypical mycobacterial infections in patients undergoing cardiac procedures (Fig. 1). The infections are associated with the intraoperative use of HCUs for controlled hypothermia [2].

*Mycobacterium chimaera* is a slow-growing nontuberculous mycobacterium belonging to the genus *Mycobacterium* (*Mycobacterium avium* complex – MAC). It is generically similar to *Mycobacterium intracellulare*, as described by Tortoli *et al.* in 2004 [3]. *Mycobacterium chimaera* is mostly responsible for pneumonia in patients with conditions of the respiratory system, mucoviscidosis, or immune deficits. Infections of the bones and skin have also been reported [3–5]. Postoperative infections are characterized by late clinical manifestation (the onset of the symptoms may occur as late as several years after the procedure), weak response to treatment, and poor prognosis [6]. The described bacterium occurs mostly in water environments, e.g. in water supply

installations. Identifying *M. chimaera* requires the use of molecular diagnostics consisting of 16S ribosomal RNA (rRNA) gene sequencing [2]. The first reports concerning extrapulmonary *M. chimaera* infections in cardiac surgical patients were published in 2013. Achermann *et al.* (from Switzerland) described patients undergoing cardiac surgical procedures in 2011 and 2012 who were diagnosed with, respectively, invasive prosthetic mitral valve endocarditis and sepsis with infection manifesting in multiple organs; both conditions were caused by *M. chimaera* [7]. The attention of the researchers was drawn to the occurrence of the very rare infections in a relatively short time frame; therefore, diagnostics were extended, and an epidemiological investigation was conducted [7]. Genotyping using the RAPD-PCR technique (random amplification of polymorphic DNA – polymerase chain reaction) demonstrated that the same strain of *M. chimaera* was isolated from both patients. Further investigation revealed that *M. chimaera* strains were present in the water tanks and circuits of heater-cooler devices [8].

In 2014, the Swiss Federal Office of Public Health informed about patients suffering from *M. chimaera* infections who had undergone cardiac procedures using con-

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Year	Event
2012	<ul style="list-style-type: none"> <li>– First isolation of <i>M. chimaera</i> from water samples</li> <li>– First isolation of <i>M. chimaera</i> from a cardiac surgical patients</li> </ul>
2013	<ul style="list-style-type: none"> <li>– <i>M. chimaera</i> isolates of cardiac surgical patients are found to be related</li> <li>– First isolation of <i>M. chimaera</i> from a pediatric patient undergoing cardiac surgery</li> <li>– First isolation of <i>M. chimaera</i> from air samples</li> </ul>
2014	<ul style="list-style-type: none"> <li>– Further reports from all over the globe concerning <i>M. chimaera</i> infections in cardiac patients</li> <li>– First isolation of <i>M. chimaera</i> from factory – new heater-cooler units (HCUs)</li> <li>– Confirmation of HCU production line contamination with <i>M. chimaera</i></li> <li>– Changes introduced to the HCU production line to prevent <i>M. chimaera</i> contamination</li> </ul>
2015	
2016	<ul style="list-style-type: none"> <li>– Recommendations from the Food and Drug Administration concerning the use of HCUs with regards to the risk of <i>M. chimaera</i> contamination</li> </ul>

**Fig. 1.** Timeline of important events related to the study of *Mycobacterium chimaera* infections in cardiac surgical patients

taminated HCUs [9]. Further reports stated that HCUs from one manufacturer could be contaminated [2, 5, 10–12].

The HCUs are widely used in both adult and pediatric cardiac surgery. They maintain proper temperature of the blood flowing through the extracorporeal circulation machine, ensure proper temperature of cardioplegia, and can be used to control the temperature of warming mattresses. The heat-exchange system of an HCU includes a water tank, which may be a reservoir of various microorganisms. Although the water in the device's circuit does not come into direct contact with the patient's blood, there is a possibility that contaminated water may become aerosolized and be vented into the air outside [1]. Studies conducted on the subject proved that *M. chimaera* may be present in the air surrounding the heater-cooler unit; therefore, air is assumed to be the most likely medium of microbial transmission from water to the patient's body during open chest surgery [10, 12, 13].

The first reports concerning remote *M. chimaera* infections in patients treated with cardiac surgery were followed by reports of further patients treated in hospitals worldwide. So far, the available literature includes descriptions of over 70 such cases, and the mortality rate associated with these infections is approximately 50% despite the use of antibiotic treatment [11, 12]. A Swiss publication by Sax *et al.* identified 6 patients in whom the time between the cardiac procedure and clinical manifestation ranged from 1.5 to 3.6 years [2]. The clinical symptoms of *M. chimaera* in this group included fatigability, fever, hepatitis, renal failure, splenomegaly, and pancytopenia [2]. In 5 patients, echocardiographic signs of infective endocarditis (IE) were observed on the cardiac implants. The patients in the described study were treated with a combination of clarithromycin, rifabutin, and ethambutol, combined with either amikacin or moxifloxacin. Three out of the five patients were diagnosed with breakthrough infections with splenic embolism, pacemaker pocket infection, and progressive mitral valve endocarditis. Three patients underwent replacement of the infected valve, and one patient required repeated surgical debridement of the infection site. Two patients died despite antibiotic treatment [2].

In a report by Haller *et al.* from 2016, describing German experiences with *M. chimaera* in cardiac surgery, infections

were observed in 5 patients (age: 53–80) treated in 3 centers [5]. Four of these patients were implanted with prosthetic material, and one underwent coronary artery bypass grafting alone. The times between the cardiac procedure and the manifestation of infection symptoms ranged from 5 months to 5 years. Investigation of heater-cooler units in 78 German cardiac surgery centers demonstrated HCU contamination in 26 cases; however, it should be noted that the findings did not pertain only to *M. chimaera*, but also included other microorganisms such as *Pseudomonas aeruginosa*, *Legionella pneumophila*, *Stenotrophomonas maltophilia*, and fungi [5].

*Mycobacterium chimaera* infections associated with cardiac surgery mostly affect adult patients; however, Kohler *et al.* described the first case of such infection in a neonate with a congenital heart defect, who underwent cardiac surgery consisting in aortic coarctation repair with pulmonary artery banding [11]. The child experienced episodes of fever and loss of appetite. The conducted examinations confirmed infection of the prosthetic band and an inflammatory (mycotic) aneurysm of the pulmonary artery. It should be noted that, although the cardiac procedure in the described child was conducted without extracorporeal circulation, microbial transmission from an HCU to the patient's body occurred most likely due to the use of a warming mattress connected to an HCU; this is a common clinical practice in pediatric cardiac surgery, which is also used in our center. Apart from the pediatric patient, Kohler *et al.* also described the cases of 9 adults with *M. chimaera* infections after cardiac procedures. It is worth noting that the median time from the procedure to the onset of symptoms was 18 months (11–40 months) [11].

In October 2016, American data concerning *M. chimaera* infections in U.S. patients were updated, identifying 11 patients infected after cardiac surgical procedures [13]. The conducted epidemiological investigation demonstrated that *M. chimaera* strains isolated from different centers were nearly identical, which provides support for the hypothesis that they may have originated from contaminated HCUs manufactured in a single production plant [13]. These results confirm the observations made by European researchers, who examined samples from 3 centers from different Eu-

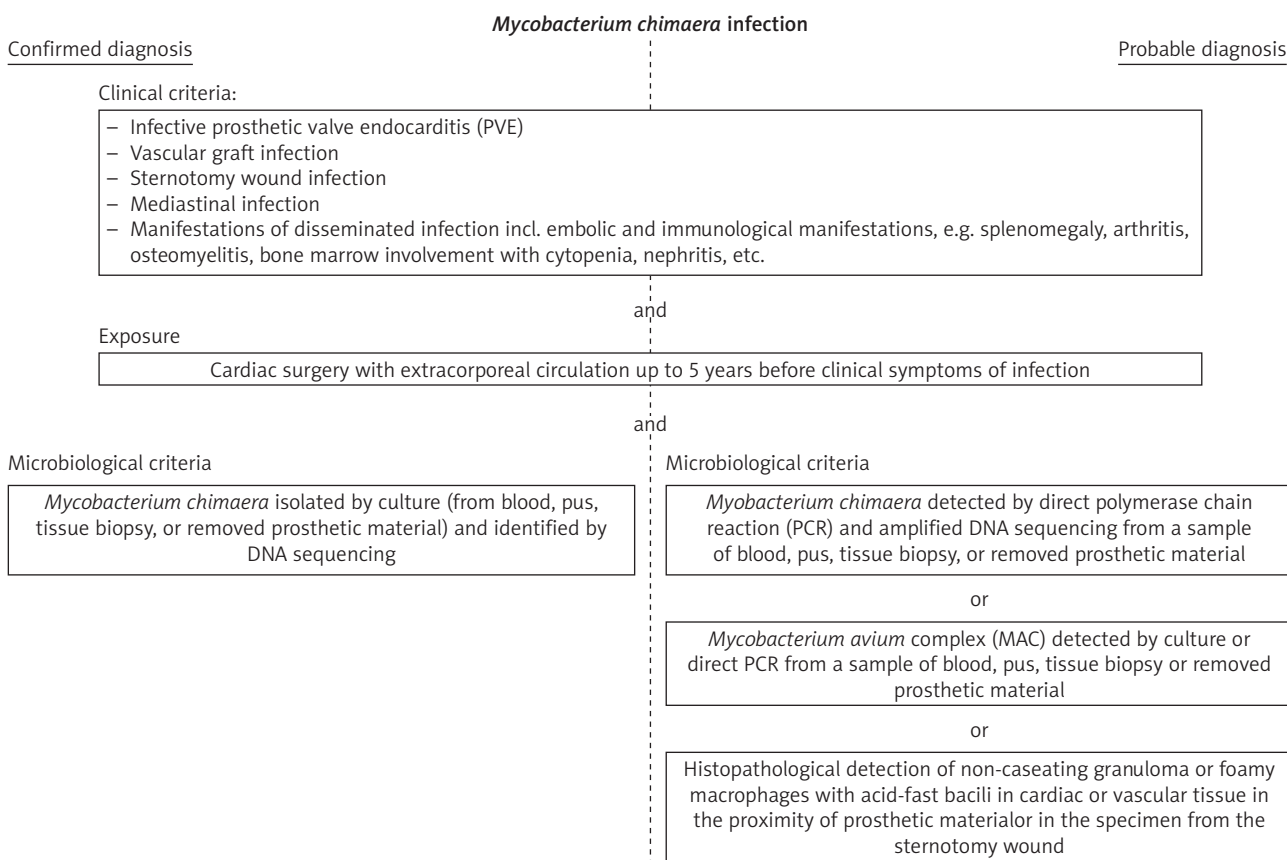
European countries and one HCU production plant, coming to the conclusion that the infection originated from HCUs contaminated at the production stage [11, 12, 14]. Independent genetic studies on microorganisms isolated from HCUs in different countries also concluded that the contamination most likely occurred in a single location (a so-called point-source contamination) during production [5, 13].

It should be underscored that the HCU manufacturer remained in constant contact with the users, recommending additional actions concerning the disinfection and sanitation of the devices. These recommendations were also distributed in Poland. Moreover, Haller *et al.* reported that the HCU manufacturer, on its own initiative, conducted environmental studies at the HCU production plant in August 2014, confirming the contamination of the production line and the water supply system with *M. chimaera* [1, 5]. In September 2014, the manufacturer introduced cleaning and disinfecting procedures to the production line; the devices manufactured after September 2014 are believed to be free from *M. chimaera* contamination [1].

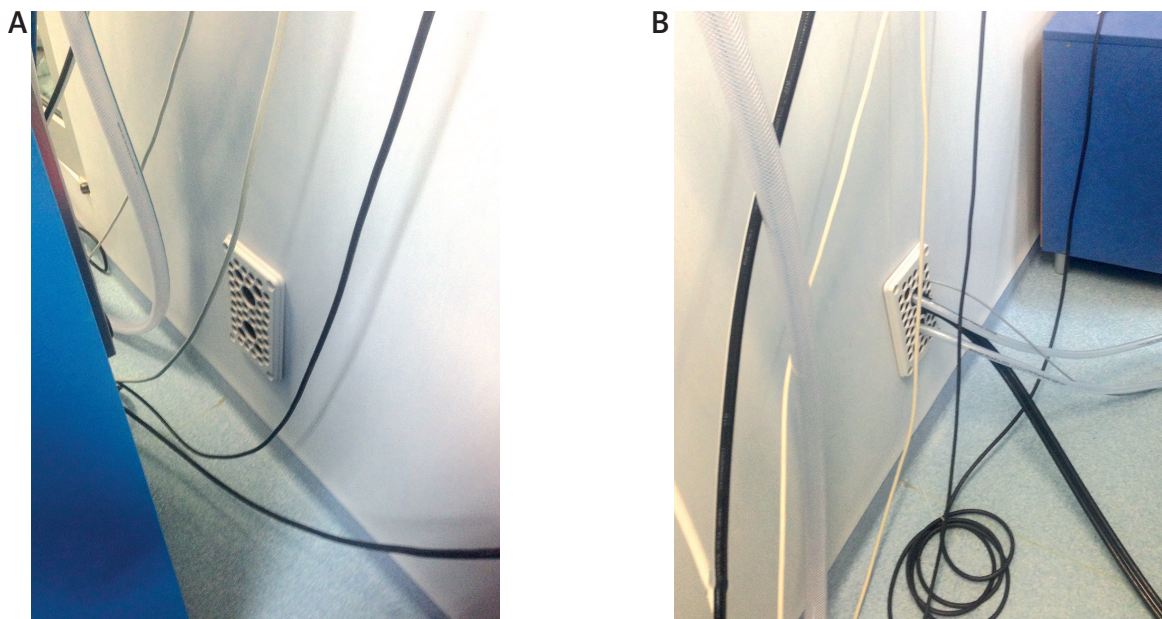
To the best of our knowledge, no *M. chimaera* infection has yet been noted in Poland in patients treated with cardiac surgery; nevertheless, the potential risk of this complication should be considered in everyday clinical practice. Until certain and universal methods of preventing HCU contamination and procedures for disinfection and safe use of these devices are established, it seems reasonable

to act in accordance with the suggestions of the manufacturers and recommendations issued by reference organizations. The guidelines published by the Centers for Disease Control and Prevention (CDC) and FDA pertain primarily to devices manufactured before September 2014 and stress that the air vented from the HCU should be prevented from coming into contact with the environment of the surgical field [1, 13]. Also, the device's manufacturer recommends disinfecting the HCUs according to defined procedures. However, Schreiber *et al.* demonstrated that this may prove ineffective – despite the intensification of disinfection procedures, the contamination of HCUs persisted [15]. The researchers believe that the proliferation of mycobacteria and the development of biofilm in the device can be facilitated by corrosion, characteristics of materials used for HCU production, and so-called dead spaces in the structure of the device.

Additionally, it has been underscored that performing microbiological testing to exclude or confirm HCU contamination is not currently recommended due to the complexity of the required methodology and the high rate of false negative results [1, 16]. In 2015, the European Centre for Disease Prevention and Control (ECDC) published a detailed methodology for culturing biological materials and performing molecular diagnostics in order to detect *M. chimaera* [8]. These guidelines also include criteria for identifying probable and confirmed cases of *M. chimaera* infections (Fig. 2) [8].



**Fig. 2.** Criteria for diagnosing *Mycobacterium chimaera* in cardiac surgical patients according to the European Centre for Disease Prevention and Control [8]



**Fig. 3.** Modifications made to the operating room on the Pediatric Cardiac Surgery Ward in Gdansk in order to move the heater-cooler unit outside the operating room (A), the control cable and water connections passing through the wall of the operating room (B)

Although the awareness of the medical community regarding *M. chimaera* infections is continuously improving, questions pertaining to the management of patients at risk of these infections, the methods of securing HCUs, and prophylactic actions still require some clarification [2]. As demonstrated by Sommerstein *et al.*, the high risk of microbial transmission through air associated with the use of HCUs is also present in operating rooms adhering to the highest standards of air cleanliness [10]. Therefore, the simplest method of protecting the patient from infection seems to be to completely isolate the environment of the operating room from the air vented by HCUs. This can be achieved by moving the HCU outside the operating room and controlling it remotely. This method usually does not require extensive technical works in the operating theater and is not associated with high expenses. In our center, the HCU was moved outside the operating room, which was done with little expenditure (Fig. 3). Nonetheless, other actions limiting the occurrence of hospital infections at cardiac surgery wards (obtaining microbiological cultures from patients, proper perioperative antibiotic prophylaxis, and hand hygiene) should not be neglected [17–19]. Reorganizing operating rooms to isolate the HCUs can be effective not only in preventing *M. chimaera* infections, but also in preventing wound infections with other pathogens that can hypothetically colonize the heater-cooler devices. This strategy is in accordance with the recommendations of experts and HCU manufacturers, and it may be useful during the building and reorganizing of operating rooms used for the purposes of cardiac surgery.

In conclusion, it should be underscored that HCUs can be a source of bacterial infections in patients undergoing cardiac surgery [2]. The risk is mostly associated with the use of heater-cooler units manufactured before September

2014, but it seems reasonable to also apply the recommendations from institutions responsible for prevention of infection to all HCUs from all manufacturers as well as to all devices that may generate aerosols in the operating room. The simplest method of preventing surgical field contamination by air vented from an HCU seems to be to move the device outside the operating room and act in accordance with the manufacturer's guidelines. Performing microbiological testing in order to confirm or exclude HCU contamination with *M. chimaera* is not currently recommended. It is advisable to monitor the scientific reports concerning this subject, as the information on *M. chimaera* infections in cardiac surgical patients is updated every few months. In the case of unexplained infections (especially those occurring in the long-term postoperative period) in cardiac surgical patients, the possibility of *M. chimaera* infection should be considered.

### Disclosure

Authors report no conflict of interest.

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