Epidemiological and clinical characteristics of *Streptococcus tigurinus* endocarditis

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Abstract

**Background:** *Streptococcus tigurinus* was recently described as a new streptococcal species within the viridans group streptococci (VGS). The objectives of the present work were to analyse the clinical and microbiological characteristics of *S. tigurinus* isolated from patients with bacteraemias, to determine the prevalence of *S. tigurinus* among VGS endocarditis in Spain, and to compare the clinical characteristics and outcomes of endocarditis caused by *S. tigurinus* and other VGS.

**Methods:** Retrospective nationwide study, performed between 2008 and 2016 in 9 Spanish hospitals from 7 different provinces comprising 237 cases of infective endocarditis. Streptococcal isolates were identified by sequencing fragments of their 16S rRNA, sodA and groEL genes. Clinical data of patients with streptococcal endocarditis were prospectively collected according to a pre-established protocol.

**Results:** Patients with endocarditis represented 7/9 (77.8%) and 26/86 (30.2%) of the bacteraemias caused by *S. tigurinus* and other VGS, respectively (*p* < 0.001), in two of the hospital participants. Among patients with streptococcal endocarditis, 12 different *Streptococcus* species were recognized being *S. oralis*, *S. tigurinus* and *S. mitis* the three more common. No relevant statistical differences were observed in the clinical characteristics and outcomes of endocarditis caused by the different VGS species.

**Conclusions:** In this multicenter study performed in Spain, *S. tigurinus* showed a higher predilection for the endocardial endothelium as compared to other VGS. However, clinical characteristics and outcomes of endocarditis caused by *S. tigurinus* did not significantly differ from endocarditis caused by other oral streptococci.

**Keywords:** *Streptococcus Viridans*, Infective endocarditis, Multicentre studies, Epidemiologic surveillance, Antibiotic resistance

Background

*Streptococcus tigurinus* was firstly described as a new streptococcal species in 2012 based on DNA hybridization analysis and 16S rRNA sequencing, being genetically very similar to *Streptococcus oralis* [1]. In fact, in 2016, and based on whole-genome sequencing, it was proposed to classify *S. tigurinus* as a *Streptococcus oralis* subspecies [2]. *S. tigurinus*, as other mitis group streptococci has been found as a commensal of the human oral cavity although since its initial description it has been also documented as a causative agent of infective endocarditis (IE) and other infections as meningitis, spondylodiscitis, osteomyelitis, prosthetic infections, etc. [1, 3–7]. The objective of the present study was to establish the clinical and microbiological characteristics of *S. tigurinus* isolated from patients with bacteraemias, to determine the prevalence of *S. tigurinus* among the cases of viridans group streptococci (VGS) endocarditis in Spain, and to...
compare the outcomes of IE caused by \textit{S. tigurinus} and by other VGS.

\textbf{Methods}

\textbf{\textit{S. tigurinus} prevalence study}

To study the relevance of finding \textit{S. tigurinus} in a blood culture, all VGS isolated from blood cultures collected between 2008 and 2016 in 9 Spanish hospitals located in 7 different provinces comprising 237 cases of IE was performed. Diagnosis of IE was done according to the revised Duke diagnostic criteria [8]. Clinical IE data were prospectively collected according to a pre-established protocol [9]. Only cases with definite IE diagnosis were included in the study.

\textbf{Microbiological techniques}

VGS isolates were identified by sequencing fragments of their 16S rRNA, sodaA and groEL genes and comparing them with those available at the NCBI and LeBibi databases [10]. A similitude of > 99% with the 3 genes was considered for a correct species identification. All \textit{S. tigurinus} detected were genotyped by MLST according to the established protocol at the Oral Streptococcus MLST Database web page (https://pubmlst.org/oralstrep/). Antimicrobial MICs were determined by the broth microdilution method using Iso-Sensitest Broth (Oxoid) supplemented with lysed horse blood 5% v/v. After incubation for 24 h at 35 °C, susceptibility results were read and interpreted according to CLSI guidelines. \textit{S. pneumoniae} ATCC 49619 was used as control.

\textbf{Statistical analysis}

The unpaired t-test or the chi-square test (Fisher’s exact test when appropriate) was used to compare continuous and categorical variables, respectively. All statistical analyses were performed using the online available GraphPad software (www.graphpad.com/quickcalcs/).

\textbf{Ethical considerations}

The project and the common case report form were approved by the national and local institutional review boards and ethics committees (E.C. 18/07) and all patients gave their written informed consent to participate in the study.

\textbf{Results}

In the present work, 169 VGS isolates were identified by molecular methods: 95 from the prevalence study and 74 from the study of IE. The 16S rRNA gene correctly identified all of them, sodaA misidentified one \textit{S. oralis} isolate as \textit{S. tigurinus} and groEL misidentified 5 \textit{S. oralis} isolates as \textit{S. tigurinus} (n = 2), \textit{S. cristatus} (n = 2) and \textit{S. mitis} (n = 1).

\textbf{\textit{S. tigurinus} prevalence study}

Overall, 95 cases of VGS bacteraemias recorded in the hospitals of Barcelona and San Sebastian were studied, being 9 identified as \textit{S. tigurinus}. Patients with endocarditis represented 7/9 (77.8%) of the \textit{S. tigurinus} and 26/86 (30.2%) of the remaining VGS (p = 0.008). This data suggests a bigger attraction of \textit{S. tigurinus} for the endocardial endothelium as compared with related species of the VGS, a finding that has been also observed in other studies [6].

\textbf{\textit{S. tigurinus} endocarditis study}

Of the 237 IE caused by VGS recorded in the study, 74 isolates were available for further studies and were identified by phenotypic methods and by gene sequencing. In global, 12 different \textit{Streptococcus} species were recognized being \textit{S. oralis}, \textit{S. tigurinus} and \textit{S. mitis} the three more common causing 37.8, 23.0 and 21.6% of IE cases respectively (Table 1). All \textit{S. tigurinus} had been previously identified by phenotypic methods as \textit{S. oralis} and were found in 5/9 hospitals and in 4/7 provinces. All \textit{S. tigurinus} were fully susceptible to oral penicillin, amoxicillin, and cefotaxime except one isolate that had a penicillin MIC = 0.12 mg/L. Three isolates were tetracycline-resistant (MIC> 4 mg/L) and another three erythromycin-resistant (MIC = 2 mg/L). All \textit{S. tigurinus} isolates were susceptible to clindamycin, levofloxacin and vancomycin. A large heterogeneity of \textit{S. tigurinus} was observed by MLST, having all different ST. Among the 17 \textit{S. tigurinus} isolates, there were only two ST

\begin{table}[h]
\centering
\caption{Species of viridans group streptococci causing infective endocarditis in Spain, 2008–2016}
\begin{tabular}{lll}
\hline
Species & n & % \\
\hline
\textit{S. oralis} & 28 & 37.8\% \\
\textit{S. tigurinus} & 17 & 23.0\% \\
\textit{S. mitis} & 16 & 21.6\% \\
\textit{S. parasanguinis} & 3 & 4.1\% \\
\textit{S. sanguinis} & 2 & 2.7\% \\
\textit{S. pneumoniae} & 2 & 2.7\% \\
\textit{S. infantis} & 1 & 1.4\% \\
\textit{S. salivarius} & 1 & 1.4\% \\
\textit{S. infantarius} & 1 & 1.4\% \\
\textit{S. gordonii} & 1 & 1.4\% \\
\textit{S. anginosus} & 1 & 1.4\% \\
\textit{S. alactolyticus} & 1 & 1.4\% \\
\hline
Total & 74 & \\
\hline
\end{tabular}
\end{table}
Table 2 Clinical data of patients with infective endocarditis caused by *S. mitis*, *S. oralis*, *S. tigurinus* and other viridans group streptococci, Spain, 2008–2016

| Demographics | *S. mitis* (n = 16) | *S. oralis* (n = 28) | *S. tigurinus* (n = 17) | Other VGS (n = 13) |
|--------------|---------------------|----------------------|-----------------------|-------------------|
| Age in years: average ± SD (range) | 58.4 ± 17.5 (35–94) | 60.0 ± 16.7 (32–86) | 66.7 ± 17.2 (19–87) | 61.2 ± 13.9 (28–80) |
| Female/Male | 2/14 | 4/24 | 6/11 | 5/8 |
| Underlying conditions | | | | |
| Diabetes mellitus | 2 | 2 | 0 | 0 |
| Renal insufficiency | 0 | 1 | 2 | 1 |
| Pulmonary disease | 3 | 2 | 3 | 1 |
| Neoplasm | 2 | 2 | 3 | 1 |
| HIV infection | 0 | 3 | 0 | 1 |
| Risk factors | | | | |
| Previous infective endocarditis | 2 | 5 | 2 | 1 |
| Heart failure | 1 | 4 | 4 | 2 |
| Atrial fibrillation | 3 | 4 | 2 | 1 |
| Site of acquisition | | | | |
| Nosocomial | 0 | 0 | 0 | 0 |
| Community-acquired | 15 | 27 | 16 | 12 |
| Health care-related | 1 | 1 | 1 | 1 |
| Symptoms at admission | | | | |
| Affected valve | | | | |
| Aortic | 6 | 14 | 7 | 7 |
| Mitral | 6 | 9 | 6 | 2 |
| Aortic + mitral | 2 | 3 | 2 | 2 |
| Tricuspid | 1 | 0 | 0 | 0 |
| Tricuspid + mitral | 0 | 0 | 0 | 1 |
| Aortic + tricuspid + mitral | 0 | 1 | 0 | 0 |
| Pulmonary | 1 | 0 | 0 | 0 |
| Ductus arteriosus | 0 | 0 | 0 | 1 |
| Not determined | 0 | 1 | 2 | 0 |
| Presentation | | | | |
| Fever > 38 °C | 16 | 23 | 13/16 | 11 |
| Splinter hemorrhages | 1 | 0 | 0 | 2 |
| Osler nodes | 0 | 0 | 0 | 1 |
| Janeway lesions | 1 | 0 | 0 | 1 |
| New murmur | 3 | 15 | 5/16 | 8 |
| Worsening of old murmur | 0 | 4/24 | 1/15 | 0 |
| Protein C reactive: average ± SD (range) | 74.2 ± 41.5 (13–168) | 55.7 ± 45.6 (1–138) | 52.3 ± 96.4 (3–356) | 40.8 ± 42.7 (3–101) |
| Elevated Rheumatoid factor | 0/2 | 4/11 | 1/4 | 2/4 |
| Vegeations | | | | |
| Not found | 6 | 6 | 6 | 4 |
| Aortic | 4 | 10 | 6 | 5 |
| Mitral | 3 | 7 | 3 | 1 |
| Tricuspid | 1 | 0 | 0 | 0 |
| Aortic + mitral | 1 | 5 | 2 | 2 |
previously defined in the MLST database, ST30 and ST65, both previously identified as *S. oralis* from patients with gingivitis. Comparing IE caused by *S. tigurinus* and other VGS, patients’ average age was higher for *S. tigurinus* endocarditis, without statistical significance (*p* = 0.179 compared to *S. mitis*) (Table 2). No relevant statistical differences were observed in the clinical characteristics of IE caused by the different VGS species. Left heart valves were more frequently affected in *S. tigurinus* IE as well as in other streptococci: 45.9% mitral, 31.1% aortic, and 13.6% both valves. Considering all VGS IE, perforation was the most common intracardiac complication (16.2%), followed by abscess (10.8%) and pseudoaneurysm alone (2.7%) or with perforation (2.7%). In-hospital overall mortality in VGS IE (10.8%) was relatively high as compared with other studies [11]. Mortality due to *S. tigurinus* was quite similar to that of *S. oralis* (11.3% vs 14.8%, *p* = 1). Surprisingly, no mortality was recorded for any of the 16 patients with *S. mitis* IE that was also the group with less patients requiring surgical treatment. Of the patients with IE caused by VGS, 22 were treated only with betalactams (20 with ceftriaxone, 1 with ceftriaxone and ampicillin and 1

### Table 2 Clinical data of patients with infective endocarditis caused by *S. mitis*, *S. oralis*, *S. tigurinus* and other viridans group streptococci, Spain, 2008–2016 (Continued)

|                     | *S. mitis* (*n* = 16) | *S. oralis* (*n* = 28) | *S. tigurinus* (*n* = 17) | Other VGS (*n* = 13) |
|---------------------|-----------------------|-------------------------|---------------------------|----------------------|
| Mitral + tricuspid  | 0                     | 0                       | 0                         | 1                    |
| Chordae tendinae    | 1                     | 0                       | 0                         | 0                    |
| Intracardiac complications |
| Perforation         | 2                     | 4                       | 3                         | 3                    |
| Abscess             | 1                     | 4                       | 1                         | 2                    |
| Pseudoaneurysm      | 0                     | 1                       | 0                         | 1                    |
| Pseudoaneurysm & perforation | 0                | 2                       | 0                         | 0                    |
| NC                  | 0                     | 1                       | 0                         | 2                    |
| Clinical course     |
| Embolism            | 1                     | 6/27*                   | 5/16*                     | 4                    |
| New heart failure   | 1                     | 12/27*                  | 5                          | 4                    |
| Persistent bacteria | 1                     | 0                       | 0                         | 1                    |
| Surgery             |
| Indicated           | 5                     | 19/27*                  | 9                          | 7                    |
| Performed           | 5                     | 18/27*                  | 6                          | 6                    |
| Criteria for surgery |
| Cardiac insufficiency | 2                   | 9                       | 2                          | 3                    |
| Early prosthetic IE | 0                     | 1                       | 0                          | 0                    |
| Late prosthetic IE  | 1                     | 2                       | 0                          | 0                    |
| Valve insufficiency | 3                     | 10                      | 3                          | 4                    |
| Embolisms           | 0                     | 1                       | 0                          | 1                    |
| Others              | 1                     | 5                       | 3                          | 1                    |
| Outcome             |
| Days hospital stay: average ± SD (range) | 32.4 ± 19.3 (9–85)  | 31.0 ± 21.8 (3–106) | 29.3 ± 17.9 (5–74) | 29.9 ± 16.3 (6–53) |
| In-hospital mortality | 0                   | 4                       | 2                          | 2                    |
| 1-year mortality    | 0/14                  | 3/22                    | 2/15                       | 1/8                  |
| Recurrence          | 0                     | 2                       | 2                          | 0                    |
| Antibiotic treatment |
| Beta-lactams alone  | 6                     | 9                       | 6                          | 5                    |
| Beta-lactams + gentamicin | 8                | 12                      | 7                          | 6                    |
| Other combinations  | 2                     | 7                       | 4                          | 2                    |

*Denominator adjusted to patients with data available

*Some patients had more than one criteria for surgery

*Excluding patients died at hospital

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with imipenem), 26 with betalactams and gentamicin, being ceftriaxone-gentamicin the combination most frequently used (in 10 patients ceftriaxone-gentamicin alone and in another 8 with a third antibiotic). There were no differences in the antibiotic treatment despite the species identified.

Discussion

Despite the advances in imaging (echocardiography and nuclear medicine), molecular microbiology and surgery, IE is still today a serious disease with high morbidity and mortality rates. In high-income countries, epidemiology of IE is changing with an increase of elderly patients with prosthetic valves or implantable cardiovascular devices [11]. Also, etiologic agents causing IE seems to be changing, with an increase of staphylococcal IE and a reduction of IE caused by VGS [11, 12]. In this Spanish multicenter study, it was previously shown that VGS represented 27.5% cases of definitive IE [13]. In the present work it has been shown that S. tigurinus was responsible for 20% of these definitive IE cases caused by VGS.

S. tigurinus has been associated to IE since its first description, although it has been also described as causing meningitis, spondylodiscitis, prosthetic infections, osteomyelitis, and periodontitis among others. However, in a recent review, IE was the most commonly reported manifestation of S. tigurinus infection [6] probably because IE has been more systematically searched for than other kind of infections. In that review, no deaths were documented among patients with S. tigurinus infection except for one case of osteomyelitis. In our study, 2 patients with S. tigurinus IE died during admission with no difference in mortality rates to IE caused by other VGS.

Besides to the oral origin of S. tigurinus infections, an enteric source has been also postulated after the translocation of the pathogen from an intraabdominal disorder [14]. However we considered that in most of our patients the origin was the oral cavity as no intraabdominal condition was found in any of the patients, whether the causative agent of the IE was S. tigurinus or another of the VSG commonly found in the oral mucosa. The oral origin of most VGS IE highlights the need of an exquisite dental care in patients with risk for IE [15].

IE caused by S. tigurinus did not clinically differ from IE caused by other VGS, showing a community-acquired origin, clinical course and outcomes in general better than bacterial IE caused by other Gram-positive bacteria as Staphylococcus aureus or Enterococcus [11]. Despite the wide genomic heterogeneity most isolates were fully susceptible to commonly used antibiotics in the treatment of IE. An endocarditis should always be suspected when a S. tigurinus is isolated from a blood culture due to the high prevalence of IE caused by this, otherwise commensal bacteria.

Conclusion

In this multicenter study performed in Spain, S. tigurinus was a common cause of IE. Clinical characteristics and outcomes of S. tigurinus endocarditis did not differ from endocarditis caused by other VGS. S. tigurinus showed a high genomic heterogeneity with most isolates susceptible in vitro to antibiotics commonly used in the treatment of IE.

Abbreviations

CLSI: Clinical and laboratory standards Institute; IE: Infective endocarditis; Mlc: Minimum inhibitory concentration; MLST: Multi-locus sequence typing; ST: Sequence-type; VGS: Viridans group streptococci.

Acknowledgements

Members of the GAMES Group (Spanish Collaboration on Endocarditis Group): Hospital Costa del Sol (Marbella): Fernando Fernández Sánchez, Mariam Nouredline, Gabriel Rosas, Javier de la Torre Lima; Hospital Universitario de Cruces, (Bilbao): José Aramendi, María José Blanco, Roberto Blanco, María Victoria Boado, Marta Campaña Lázaro, Alejandro Crespo, Josune Gorkoetxea, José Ramón Inuietagoyena, Josu Iruzun Zuaizabal, Leire López-Soria, Miguel Montejo, Javier Nieto, David Rodrigo, David Rodríguez, Regino Rodríguez, Yolanda Vitoria, Roberto Voces; Hospital Universitario Virgen de la Victoria, (Málaga): Mª Victoria García López, Radka Ivanova Georgieva, Guillermo Ojeda, Isabel Rodríguez Ballón, Josefina Ruiz Morales; Hospital Universitario Donostia-Policlinica Gipuzkoa, (San Sebastián): Ana María Cuende, Tomás Escheverría, Ana Fuente, Eduardo Gamín, Miguel Ángel Goenaga, Pedro Igidoa, José Antonio Iribarren, Alberto Izazigure Yara, Xabier Kortajarena Urríkola, Carlos Reviejo; Hospital General Universitario de Alicante, (Alicante): Rafael Carrasco, Vicente Climent, Patricio LLamas, Esperanza Merino, Joaquín Plazas, Sergio Reus; Complejo Hospitalario Universitario A Coruña, (A Coruña): Nemesio Álvarez, José María Bravo-Ferrer, Laura Castelo, José Cuencía, Pedro Llinares, Enrique Míguez Rey, María Rodríguez Mayo, Efrén Sánchez, Dolores Sousa Requejo; Complejo Hospitalario Universitario de Huelva, (Huelva): Francisco Javier Martínez; Hospital Universitario de Canarias, (Canarias): Mª del Mar Alonso, Beatriz Castro, Dácil García Rosado, Mª del Carmen Durán, Mª Antonia Miguel Gómez, Juan Lacaladza, Ibrahim Nassar; Hospital Regional Universitario de Málaga, (Málaga): Antonio Plata Ciezar, José Mª Reguera Iglesias; Hospital Universitario Central de Asturias, (Oviedo): Víctor Asená Álvarez, Carlos Costas, Jesús de la Hera, Jonathan Fernández Suárez, Lisardo Iglesias Fraile, Víctor León Arquero, José López Menéndez, Pilar Mencia Bajo, Carlos Morales, Alfonso Moreno Torrico, Carmen Palomo, Begoña Páez Martínez, Ángeles Rodríguez Esteban, Raquel Rodríguez García, Mauricio Telenti Asensio; Hospital Clinic-IDIBAPS, Universidad de Barcelona, (Barcelona): Manuel Almela, Juan Ambrosioni, Manuel Azqueta, Merel Brunet, Marta Bódor, Ramón Cartañá, Carlos Falces, Guillermma Fita, David Fuster, Cristina García de la Máría, Marta Hernández-Menesas, Jaume Llopis Pérez, Francesc Marco, José Mª Miró, Asunción Moreno, David Nicolás, Salvador Ninot, Eduardo Quintana, Carlos Paré, Daniel Pereda, Juan M. Pericás, José L. Pomar, José Ramírez, Irene Rovira, Elena Sandoval, Marta Stiges, Dolores Soy, Adrián Téllez, José Mª Tolosana, Bárbara Vidal, Jordi Villa; Hospital General Universitario Gregorio Marañón, (Madrid): Iván Adán, Javier Bermejo, Emilio Bouza, Daniel Celemín, Gregorio Cuello Caballero, Antonio Delgado Montero, Ana Fernández Cruz, Ana García Mansilla, Mª Eugenia García Leóni, Victor García Ramallo, Martha Kestler Hernández, Amaia Mari Hualaide, Mercedes Marín, Manuel Martínez-Sellés, Mª Cruz Menéndez, Patricia Muñoz, Cristina Rincón, Hugo Rodríguez-Abella, Marta Rodríguez-Criéxims, Blanca Pinilla, Ángel Pinto, Mariela Valero, Pilar Vázquez, Eduardo Verde Moreno; Hospital Universitario La Paz, (Madrid): Isabel Antonarena, Belén Loeches, Alejandro Martín Quirós, Mar Moreno, Ulises Ramírez, Verónica Rial Bastón, María Romero, Arcadii Saldaña; Hospital Universitario Marqués de Valdecilla, (Santander): Jesús Águero Balbin, Carlos Armiñan-Pazasti, Ana Arnaiz, Francisco Arnaiz de las Revillas, Manuel Cobo Belaustegui, María Carmen Farías, Concepción Farías-Alvés, Rubén Gómez Izquierdo, Iván García, Claudia González Rico, Manuel Gutiérrez-Cuadra, José Guzmán, José Zurirí Diez, Marcos Pajares, Ramón Pérez-Cabrero; Hospital Universitario Puerta de Hierro, (Madrid): Fernando Domínguez, Pablo García Pavía, Jesús González, Beatriz Orden, Antonio Ramos; Hospital Universitario Ramón y Cajal, (Madrid): Tomasa Centella, José Manuel Hermida, José Luis Moya, Pilar Martín-Dávila, Enrique Navas, Enrique Oliva, Alejandro del Río, Soledad Ruiz; Hospital Universitario Virgen de las Nieves, (Granada): Carmen members.
Funding

JMM received a personal 82020 research grant from the Institut d’Investigacions Biomèdiques August Pi i Sunyer (IDIBAPS), Barcelona, Spain during 2017–19. No funding entity played any role in the design of the study and data collection, analysis, and interpretation of data and in writing the manuscript.

Availability of data and materials

The datasets generated and analysed during the current study are not publicly available due to confidentiality but are available from the GAMEs project on reasonable request.

Authors’ contributions

ME, JMM performed bacterial molecular techniques (identification and genotyping) and antimicrobial susceptibility testing and contributed to the study conception, data acquisition, analysis and interpretation of findings, and drafting of the manuscript. MAG, CA, Ivan Keituqwa Yañez, Ana Peláez Ballesta; Hospital Son Llàtzer (Lorca-Murcia);, Eva Cascales Alcolea, Elena Escribano Lara García-Álvarez, José Antonio Oteo, Mercedes Sanz; Hospital de la Santa Creu i Sant Pau, (Barcelona): Natividad de Benito, Mercé Gurguí, Cristina Pacho, Roser Pericas, Guillem Pons; Complejo Hospitalario Universitario de Santiago de Compostela, (A Coruña): M. Álvarez, A. L. Fernández, Amparo Martínez, A. Prieto, Benito Regueru, E. Tijera, Marino Vega; Hospital Santiago Apóstol, (Vitoria): Andrés Canut Blasco, José Corder Mollot, Juan Carlos Gainzarain Arana, Oscar García Uriarte, Alejandro Martín López, Zurriñe Ortiz de Zárate, José Antonio Urturi Matos; Hospital SAS Línea de la Concepción, (Cádiz): Gladis García Domínguez, Antonio Sánchez-Porto; Hospital Clínico Universitario Virgen de la Arrixaca (Murcia): José Mª Ambas Leal, Elisa García Vázquez, Alicia Hernández Torres, Ana Blázquez, Gonzalo de la Morena Valenzuela; Hospital de Txagorritxu, (Vitoria); Ángel Alfonso, Javier Aramburu, Felicitas Elena Calvo, Alan Moreno Rodríguez, Paola Tarabini-Castellani; Hospital Virgen de la Salud, (Toledo): Eva Heredero Gálvez, Carolina Maicas Bellido, José Largo Pau, Mª Antonia Sepúlveda, Pilar Toledano Siera, Sadaif Zafar Iqbal-Mirza; Hospital Rafael Méndez, (Lorca-Murcia); Eva Cascales Alcolea, Ivan Keituqwa Yañez, Ana Peláez Ballesta; Hospital Universitario San Cecilio (Granada): Eduardo Moreno Escobar, Alejandro Peña Moreno, Valme Sánchez Cabrera, David Vinuesa García; Hospital Son Llàtzer (Palma de Mallorca): María Arribaslábea Asenjo, Carmen CIFuentes Luna, Juana Núñez Morcillo, Mª Cristina Pérez Seco, Aroa Villasolasa Gelaebert; Hospital Universitario Miguel Servet (Zaragoza): Carmen Aured Guallar, Nuria Fernández Abad, Pilar García Mangas, Marta Matamala Adell, Mª Pilar Palacín Ruiz, Juan Carlos Porres; Hospital General Universitario Santa Lucía (Cartagena): Begoña Alcaraz Vidal, Nazaret Cobos Trigueros, María Jesús Del Amor Espin, José Antonio Giner Caro, Roberto Jiménez Sánchez, Amaya Jimeno Almazán, Alejandro Ortín Freire, Monserrat Vilqueira González; Hospital Universitario Son Espases (Palma de Mallorca): Pere Pericás Ramis, Mª Ángels Ribas Blanco, Enrique Ruiz de Goepel Gómez, Laura Vidal Bonet; Complejo Hospitalario Universitario de Albacete (Albacete): Mª Carmen Bellón Munera, Elena Escribano Lara García-Álvarez, Antonio Tercero Martínez, Juan Carlos Segura Luque.

Ethics approval and consent to participate

The project and the common case report form were approved by the national and local institutional review boards and ethics committees (E.C. 18/07). All patients gave their written informed consent to participate in the study.

Consent for publication

Not applicable.

Competing interests

JMM has received consulting honoraria and/or research grants from AbbVie, Angelini, Bristol-Myers Squibb, Jansen, Genentech, Medtronic, Merck, Novartis, Gilead Sciences, and VIH Healthcare outside the submitted work. All other authors: none to declare.

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Received: 16 May 2018 Accepted: 18 March 2019

Published online: 29 March 2019

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