

# Novel Plasmid-Borne Multidrug Resistance Gene Cluster Including *lsa(E)* from a Linezolid-Resistant *Enterococcus faecium* Isolate of Swine Origin

Hongbin Si,<sup>a</sup> Wan-Jiang Zhang,<sup>b</sup> Shengbo Chu,<sup>b</sup> Xiu-Mei Wang,<sup>b</sup> Lei Dai,<sup>c</sup> Xin Hua,<sup>b</sup> Zhimin Dong,<sup>b</sup> Stefan Schwarz,<sup>d</sup> Siguo Liu<sup>b</sup>

College of Animal Sciences and Technology, Guangxi University, Nanning, China<sup>a</sup>; State Key Laboratory of Veterinary Biotechnology, Harbin Veterinary Research Institute, Chinese Academy of Agricultural Sciences, Harbin, China<sup>b</sup>; Department of Veterinary Microbiology and Preventive Medicine, College of Veterinary Medicine, Iowa State University, Ames, Iowa, USA<sup>c</sup>; Institute of Farm Animal Genetics, Friedrich-Loeffler-Institut (FLI), Neustadt-Mariensee, Germany<sup>d</sup>

**A novel nonconjugative plasmid of 28,489 bp from a porcine linezolid-resistant *Enterococcus faecium* isolate was completely sequenced. This plasmid harbored a novel type of multiresistance gene cluster that comprised the resistance genes *lnu(B)*, *lsa(E)*, *spw*, *aadE*, *aphA3*, and two copies of *erm(B)*, which account for resistance to macrolides, lincosamides, streptogramins, pleuromutilins, streptomycin, spectinomycin, and kanamycin/neomycin. Structural comparisons suggested that this plasmid might have developed from other enterococcal plasmids by insertion element (IS)-mediated interplasmid recombination processes.**

During recent years, several ABC transporters were identified in staphylococci, streptococci, and enterococci that confer combined resistance to pleuromutilins, lincosamides, and streptogramin A antibiotics (PLS<sub>A</sub>). The corresponding genes are *vga(A)* and *vga(A)v* (1), *vga(C)* (2), *vga(E)* (3), *vga(E)v* (4), *eat(A)v* (5), *sal(A)* (6, 7), *lsa(A)* (8), *lsa(C)* (9), and *lsa(E)* (10). In contrast to the aforementioned genes, the gene *lsa(B)* confers only elevated MICs to lincosamides which, however, are below the clinical breakpoints for resistance (11). The *lsa(E)* gene has been identified as part of plasmid-borne or chromosomal multiresistance gene clusters in methicillin-resistant (MRSA) and methicillin-susceptible (MSSA) *Staphylococcus aureus* (12–14), coagulase-negative or -variable staphylococci (7, 15), and *Enterococcus* spp. (16) of human and animal origin in Europe and Asia; in human *Streptococcus agalactiae* from South America (17); and, most recently, in *Erysipelothrix rhusiopathiae* of swine origin in China (18). It is believed that the basic type of these multiresistance gene clusters, which comprises the resistance genes *aadE*, *spw*, *lsa(E)*, and *lnu(B)*, has developed in *Enterococcus* spp. (10, 12, 13). In the present study, a nonconjugative plasmid from *Enterococcus faecium* that harbors a novel *lsa(E)*-carrying multiresistance gene cluster was identified and completely sequenced to gain insight into its structure and the genetic environment of *lsa(E)*.

Thirty-five enterococcal strains, including *Enterococcus faecalis* ( $n = 21$ ), *Enterococcus faecium* ( $n = 13$ ), and *Enterococcus gallinarum* ( $n = 1$ ), were isolated from a pig farm in Guangxi province, China. These isolates were investigated for the presence of the *lsa(E)* gene by PCR using previously described primers (13). The *lsa(E)* gene was detected in five *E. faecalis* isolates and one isolate each of *E. faecium* and *E. gallinarum*. The *lsa(E)* nucleotide sequences of the seven isolates were identical to those of *lsa(E)* on plasmids pV7037 from MRSA ST9 and pXD4 from *E. faecium* (13, 16). The six *E. faecalis* and *E. faecium* isolates were analyzed by multilocus sequence typing (MLST; <http://www.mlst.net/>). Antimicrobial susceptibility testing by broth microdilution (19, 20) revealed that except for the PLS<sub>A</sub> phenotype, all isolates were also resistant to erythromycin, tetracycline, streptomycin, gentamicin, kanamycin, and ciprofloxacin but susceptible to ampicillin and vancomycin. Additional resistance (or elevated MICs) to rifampin, florfenicol, or linezolid was seen in five or six of the isolates

(Table 1). Linezolid resistance was due to the previously described mutation at position 2576 (G2576T) in the 23S rRNA gene (21), while mutations in genes for the ribosomal proteins L3 and L4 or the *cfr* gene were detected by PCR and sequence analysis (22, 23).

Conjugations by filter mating and transformation experiments were conducted using *E. faecalis* JH2-2 as the recipient (24). The two *E. faecium* plasmids pXD4 and pN39 served as positive controls in transformation and conjugation experiments (16). Transconjugants and transformants were selected on brain heart infusion (BHI) agar supplemented with 10 mg/liter valnemulin and 50 mg/liter rifampin. Only one of the *lsa(E)*-positive enterococcal isolates, namely, *E. faecium* Y13, yielded a transformant after electrotransformation. This transformant (designated TY13) exhibited high MICs not only for tiamulin, valnemulin, lincomycin, and virginiamycin M1 but also for erythromycin, kanamycin, and streptomycin (Table 1). S1 nuclease pulsed-field gel electrophoresis (PFGE) combined with Southern blot analysis revealed that the *lsa(E)* gene was located on a ca. 28-kb plasmid, designated pY13. This plasmid was sequenced using the 454 Life Sciences GS FLX system (Roche), and sequence assembly was further confirmed by nine overlapping PCR assays (PCR1 to PCR9) (see Table S1 in the supplemental material). Plasmid sequence analyses, comparisons, and annotations were performed as previously described (23). The complete plasmid pY13 from *E. faecium* Y13 was 28,489 bp in size and contained 30 putative open reading frames

Received 13 June 2015 Returned for modification 17 July 2015

Accepted 20 August 2015

Accepted manuscript posted online 31 August 2015

Citation Si H, Zhang W-J, Chu S, Wang X-M, Dai L, Hua X, Dong Z, Schwarz S, Liu S. 2015. Novel plasmid-borne multidrug resistance gene cluster including *lsa(E)* from a linezolid-resistant *Enterococcus faecium* isolate of swine origin. *Antimicrob Agents Chemother* 59:7113–7116. doi:10.1128/AAC.01394-15.

Address correspondence to Siguo Liu, siguo\_liu@hvri.ac.cn, or Stefan Schwarz, stefan.schwarz@fli.bund.de.

H.S. and W.-J.Z. contributed equally to this article.

Supplemental material for this article may be found at <http://dx.doi.org/10.1128/AAC.01394-15>.

Copyright © 2015, American Society for Microbiology. All Rights Reserved.

**TABLE 1** Antimicrobial susceptibility of the seven *lsa(E)*-carrying enterococcal isolates, a transformant, and a recipient strain used in this study

Strain	MLST type	MIC (mg/liter) for <sup>a</sup> :															
		GEN	KAN	VIR M1 <sup>b</sup>	STR	LIN	TIA	VAL	ERY	FFC	TET	CIP	AMP	RIF	VAN	LZD	
<i>E. faecalis</i> 11-27	ST169	128	>256	>128	128	256	128	128	128	>256	8	64	16	1	8	1	1
<i>E. faecalis</i> 12-7	ST220	>256	>256	>128	256	256	128	128	128	>256	128	64	32	1	4	1	8
<i>E. faecalis</i> 14-1	ST146	256	>256	>128	256	128	128	128	128	>256	128	128	64	1	16	2	16
<i>E. faecalis</i> E15	ST283	128	>256	>128	256	128	128	256	>256	128	128	64	2	32	2	16	
<i>E. faecalis</i> D12-2	ST553	128	>256	>128	128	128	>128	256	>256	128	64	64	1	2	2	16	
<i>E. gallinarum</i> Y15	NA <sup>c</sup>	256	>256	128	128	128	128	64	>256	128	64	64	0.5	8	2	8	
<i>E. faecium</i> Y13	ST29	>256	>256	128	256	128	>128	128	>256	64	64	64	1	2	0.5	16	
<i>E. faecalis</i> TY13 <sup>d</sup>		2	>256	128	256	128	>128	128	>256	4	4	1	1	1	≤0.5	2	
<i>E. faecalis</i> JH2-2		2	4	2	2	4	2	2	0.5	4	2	2	1	2	1	2	

<sup>a</sup> GEN, gentamicin; STR, streptomycin; KAN, kanamycin; VIR M1, virginiamycin M1; LIN, lincomycin; TIA, tiamulin; VAL, valnemulin; ERY, erythromycin; FFC, florfenicol; TET, tetracycline; CIP, ciprofloxacin; AMP, ampicillin; RIF, rifampin; VAN, vancomycin; LZD, linezolid.

<sup>b</sup> Note that *E. faecalis* is intrinsically resistant to streptogramins.

<sup>c</sup> NA, not applicable.

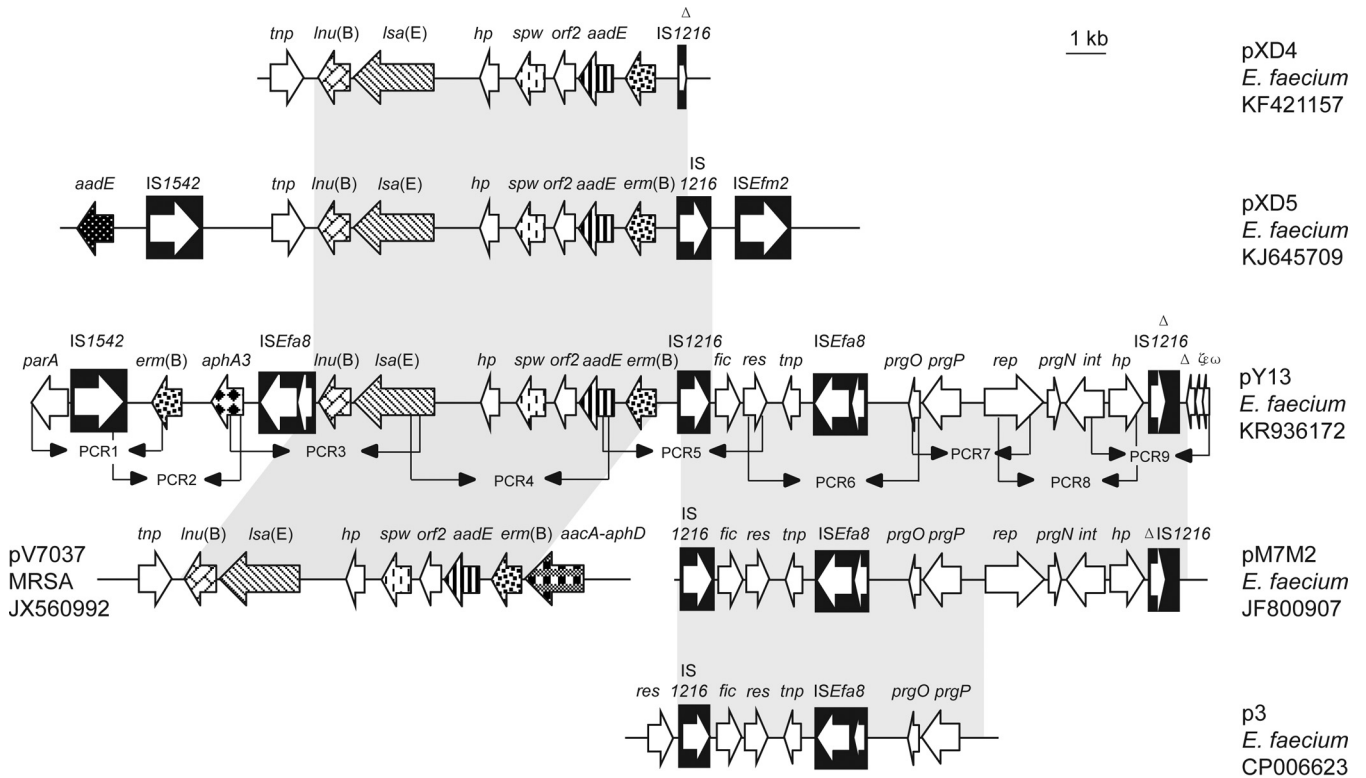
<sup>d</sup> TY13 was the transformant derived from transformation of plasmid pY13 from *E. faecium* Y13 into *E. faecalis* JH2-2.

(ORFs) (see Table S2 in the supplemental material). Based on the classification system for plasmids from enterococci and other Gram-positive bacteria described by Jensen et al. (25), plasmid pY13 is a member of the rep1 family of plasmids.

Sequence comparisons revealed a 12,461-bp region in pY13 that contained ORFs involved in plasmid replication, maintenance, and transfer and exhibited >99% identity to plasmid pM7M2 from a dairy-derived *E. faecium* isolate (26) (Fig. 1). Within this region, a 7,118-bp segment showed >99% identity to

the corresponding sequence of plasmid p3 from a vancomycin-resistant *E. faecium* ST203 isolate of human origin (27). Upstream of an *ISEfa8* element, a *prgOPN* gene cluster was detected. Previous studies demonstrated that the *prgOPN* gene cluster may represent a toxin-antitoxin-independent stabilization mechanism and may be involved in the persistence and distribution of antibiotic resistance plasmids (28, 29). The *prgP-prgO* genes may represent the most common partition cassettes in enterococci (30).

A region of 8,705 bp in pY13, which is bracketed on the left-



**FIG 1** Linear comparison of the *lsa(E)*-carrying plasmid pY13 (GenBank accession no. KR936172) with enterococcal and staphylococcal plasmids pXD4, pXD5, pM7M2, pV7037, and p3. Arrows, positions and directions of transcription of the genes; shading, regions of >99% nucleotide sequence identity in the different plasmids; black arrowheads, the nine overlapping PCRs (PCR1 to PCR9) designed to confirm the pY13 plasmid and the genetic environment of the *lsa(E)* gene; Δ, a truncated gene.

hand side by an *ISEfa8* element and on the right-hand side by an *IS1216* element, contains the five antimicrobial resistance genes *lnu(B)* (lincosamide resistance), *Isa(E)* (PLS<sub>A</sub> resistance), *spw* (spectinomycin resistance), *aadE* (streptomycin resistance), and *erm(B)* (macrolide-lincosamide-streptogramin B resistance). This region corresponded closely to the regions identified on plasmid pV7037 from MRSA ST9 (13) and on plasmids pXD4 (16) and pXD5 (31) from *E. faecium* (Fig. 1). Further downstream of *lnu(B)*, an *aphA3* gene for kanamycin/neomycin resistance and another copy of the *erm(B)* gene were detected in the pY13 sequence (Fig. 1). The MICs of the transformant TY13 (Table 1) indicated that all six antimicrobial resistance genes of plasmid pY13 are functionally active. Structural comparisons suggested that pY13 is composed of various segments, which have been found, at least in part, on other enterococcal or staphylococcal plasmids (Fig. 1). Since all of these segments are flanked by intact or truncated insertion sequences, it is possible that pY13 developed from interplasmidic recombination events in which insertion sequences, such as *ISEfa8*, *IS1216*, and *IS1542*, have been involved.

S1 nuclease-PFGE combined with Southern blotting revealed that the *Isa(E)* gene was also located on plasmids of ca. 28 kb in the remaining five *E. faecalis* isolates and on a plasmid of ca. 40 kb in the *E. gallinarum* isolate (see Fig. S1 in the supplemental material). To investigate whether a pY13-like plasmid is present in these isolates, eight overlapping PCRs were designed (Fig. 1, PCR1 to PCR9; see also Table S1 in the supplemental material) to amplify eight partly overlapping regions covering the entire sequence of pY13. Subsequently, the purified PCR products were cloned into the vector pEASY-T1 and then sequenced by primer walking (Invitrogen, Beijing, China). Results showed that all five *E. faecalis* strains carried virtually the same pY13-like plasmid except for a few nucleotide substitutions, whereas the *E. gallinarum* strain was only positive for PCR3 to PCR6. Although the reason(s) that these pY13-like plasmids were not transferrable by electrotransformation into *E. faecalis* JH2-2 remains to be elucidated, these observations suggested that pY13-like plasmids have spread among different *E. faecalis* strains and play a role in the dissemination of *Isa(E)*-carrying multiresistance gene clusters.

In conclusion, we report the first complete sequence of a *Isa(E)*-harboring plasmid from an *E. faecium* isolate of swine origin. Although nonconjugative, pY13-like plasmids may act as vectors in the dissemination of antimicrobial multiresistance within the Gram-positive gene pool.

#### Nucleotide sequence accession number.

The sequence of plasmid pY13 has been deposited in GenBank under accession no. KR936172. The sequences of the five pY13-like plasmids from *E. faecalis*, i.e., p11-27 (28,489 bp) (KT448817), pE15 (28,490 bp) (KT448821), p12-7 (28,491 bp) (KT448818), pD12 (28,491 bp) (KT448820), and p14-1 (28,492 bp) (KT448819), as well as the sequence of a 15,464-bp segment of plasmid pY15 (KT448822) from *E. gallinarum*, have also been deposited in GenBank.

#### ACKNOWLEDGMENTS

This work was funded by the Guangxi Natural Science Foundation Programs (2012GXNSFBA053052 and 2013GXNSFAA019070) and the National Natural Science Foundation of China (31201862).

The contribution of S.S. was funded by the German Federal Ministry

of Education and Research (BMBF) through the German Aerospace Center (DLR) (01KI1301D [MedVet-Staph II]).

We thank X. D. Du (Henan Agricultural University) for providing plasmids pXD4 and pN39 as controls for conjugation and transformation experiments.

#### REFERENCES

- Gentry DR, McCloskey L, Gwynn MN, Rittenhouse SF, Scangarella N, Shawar R, Holmes DJ. 2008. Genetic characterization of Vga ABC proteins conferring reduced susceptibility to pleuromutilins in *Staphylococcus aureus*. *Antimicrob Agents Chemother* 52:4507–4509. <http://dx.doi.org/10.1128/AAC.00915-08>.
- Kadlec K, Schwarz S. 2009. Novel ABC transporter gene, *vga(C)*, located on a multiresistance plasmid from a porcine methicillin-resistant *Staphylococcus aureus* ST398 strain. *Antimicrob Agents Chemother* 53:3589–3591. <http://dx.doi.org/10.1128/AAC.00570-09>.
- Schwendener S, Perreten V. 2011. New transposon Tn6133 in methicillin-resistant *Staphylococcus aureus* ST398 contains *vga(E)*, a novel streptogramin A, pleuromutilin, and lincosamide resistance gene. *Antimicrob Agents Chemother* 55:4900–4904. <http://dx.doi.org/10.1128/AAC.00528-11>.
- Li J, Li B, Wendlandt S, Schwarz S, Wang Y, Wu C, Ma Z, Shen J. 2014. Identification of a novel *vga(E)* gene variant that confers resistance to pleuromutilins, lincosamides and streptogramin A antibiotics in staphylococci of porcine origin. *J Antimicrob Chemother* 69:919–923. <http://dx.doi.org/10.1093/jac/dkt482>.
- Isnard C, Malbruny B, Leclercq R, Cattoir V. 2013. Genetic basis for *in vitro* and *in vivo* resistance to lincosamides, streptogramins A, and pleuromutilins (LS<sub>A</sub>P phenotype) in *Enterococcus faecium*. *Antimicrob Agents Chemother* 57:4463–4469. <http://dx.doi.org/10.1128/AAC.01030-13>.
- Hot C, Berthet N, Chesneau O. 2014. Characterization of *sal(A)*, a novel gene responsible for lincosamide and streptogramin A resistance in *Staphylococcus sciuri*. *Antimicrob Agents Chemother* 58:3335–3341. <http://dx.doi.org/10.1128/AAC.02797-13>.
- Wendlandt S, Kadlec K, Fefßler AT, Schwarz S. 2015. Identification of ABC transporter genes conferring combined pleuromutilin-lincosamide-streptogramin A resistance in bovine methicillin-resistant *Staphylococcus aureus* and coagulase-negative staphylococci. *Vet Microbiol* 177:353–358. <http://dx.doi.org/10.1016/j.vetmic.2015.03.027>.
- Singh KV, Weinstock GM, Murray BE. 2002. An *Enterococcus faecalis* ABC homologue (*Lsa*) is required for the resistance of this species to clindamycin and quinupristin-dalfopristin. *Antimicrob Agents Chemother* 46:1845–1850. <http://dx.doi.org/10.1128/AAC.46.6.1845-1850.2002>.
- Malbruny B, Werno AM, Murdoch DR, Leclercq R, Cattoir V. 2011. Cross-resistance to lincosamides, streptogramins A, and pleuromutilins due to the *Isa(C)* gene in *Streptococcus agalactiae* UCN70. *Antimicrob Agents Chemother* 55:1470–1474. <http://dx.doi.org/10.1128/AAC.01068-10>.
- Wendlandt S, Lozano C, Kadlec K, Gomez-Sanz E, Zarazaga M, Torres C, Schwarz S. 2013. The enterococcal ABC transporter gene *Isa(E)* confers combined resistance to lincosamides, pleuromutilins and streptogramin A antibiotics in methicillin-susceptible and methicillin-resistant *Staphylococcus aureus*. *J Antimicrob Chemother* 68:473–475. <http://dx.doi.org/10.1093/jac/dks398>.
- Kehrenberg C, Ojo KK, Schwarz S. 2004. Nucleotide sequence and organization of the multiresistance plasmid pSCFS1 from *Staphylococcus sciuri*. *J Antimicrob Chemother* 54:936–939. <http://dx.doi.org/10.1093/jac/dkh457>.
- Lozano C, Aspiroz C, Saenz Y, Ruiz-Garcia M, Royo-Garcia G, Gomez-Sanz E, Ruiz-Larrea F, Zarazaga M, Torres C. 2012. Genetic environment and location of the *lnu(A)* and *lnu(B)* genes in methicillin-resistant *Staphylococcus aureus* and other staphylococci of animal and human origin. *J Antimicrob Chemother* 67:2804–2808. <http://dx.doi.org/10.1093/jac/dks320>.
- Li B, Wendlandt S, Yao J, Liu Y, Zhang Q, Shi Z, Wei J, Shao D, Schwarz S, Wang S, Ma Z. 2013. Detection and new genetic environment of the pleuromutilin-lincosamide-streptogramin A resistance gene *Isa(E)* in methicillin-resistant *Staphylococcus aureus* of swine origin. *J Antimicrob Chemother* 68:1251–1255. <http://dx.doi.org/10.1093/jac/dkt015>.
- Wendlandt S, Li J, Ho J, Porta MA, Fefßler AT, Wang Y, Kadlec K, Monecke S, Ehrlich R, Boost M, Schwarz S. 2014. Enterococcal multi-

- resistance gene cluster in methicillin-resistant *Staphylococcus aureus* from various origins and geographical locations. *J Antimicrob Chemother* 69: 2573–2575. <http://dx.doi.org/10.1093/jac/dku137>.
15. Silva NC, Guimarães FF, de Manzi PM, Gómez-Sanz E, Gómez P, Araújo-Júnior JP, Langoni H, Rall VL, Torres C. 2014. Characterization of methicillin-resistant coagulase-negative staphylococci in milk from cows with mastitis in Brazil. *Antonie Van Leeuwenhoek* 106:227–233. <http://dx.doi.org/10.1007/s10482-014-0185-5>.
  16. Li XS, Dong WC, Wang XM, Hu GZ, Wang YB, Cai BY, Wu CM, Wang Y, Du XD. 2014. Presence and genetic environment of pleuromutilin-lincosamide-streptogramin A resistance gene *lsa(E)* in enterococci of human and swine origin. *J Antimicrob Chemother* 69:1424–1426. <http://dx.doi.org/10.1093/jac/dkt502>.
  17. Montilla A, Zavala A, Cáceres Cáceres R, Cittadini R, Vay C, Gutkind G, Famiglietti A, Bonofiglio L, Mollerach M. 2014. Genetic environment of the *Inu(B)* gene in a *Streptococcus agalactiae* clinical isolate. *Antimicrob Agents Chemother* 58:5636–5637. <http://dx.doi.org/10.1128/AAC.02630-14>.
  18. Zhang A, Xu C, Wang H, Lei C, Liu B, Guan Z, Yang C, Yang Y, Peng L. 2015. Presence and new genetic environment of pleuromutilin-lincosamide-streptogramin A resistance gene *lsa(E)* in *Erysipelothrix rhusiopathiae* of swine origin. *Vet Microbiol* 177:162–167. <http://dx.doi.org/10.1016/j.vetmic.2015.02.014>.
  19. Clinical and Laboratory Standards Institute. 2013. Performance standards for antimicrobial disk and dilution susceptibility tests for bacteria isolated from animals; 2nd informational supplement. CLSI document VET01-S2. Clinical and Laboratory Standards Institute, Wayne, PA.
  20. Clinical and Laboratory Standards Institute. 2013. Performance standards for antimicrobial susceptibility testing; 23rd informational supplement. CLSI document M100-S23. Clinical and Laboratory Standards Institute, Wayne, PA.
  21. Tewhey R, Gu B, Kelesidis T, Charlton C, Bobenchik A, Hindler J, Schork NJ, Humphries RM. 2014. Mechanisms of linezolid resistance among coagulase-negative staphylococci determined by whole-genome sequencing. *mBio* 5:e00894-4. <http://dx.doi.org/10.1128/mBio.00894-14>.
  22. Patel SN, Memari N, Shahinas D, Toye B, Jamieson FB, Farrell DJ. 2013. Linezolid resistance in *Enterococcus faecium* isolated in Ontario, Canada. *Diagn Microbiol Infect Dis* 77:350–353. <http://dx.doi.org/10.1016/j.diagmicrobio.2013.08.012>.
  23. Zhang WJ, Wang XM, Dai L, Hua X, Dong Z, Schwarz S, Liu S. 2015. Novel conjugative plasmid from *Escherichia coli* of swine origin that co-harbors the multiresistance gene *cfr* and the extended-spectrum- $\beta$ -lactamase gene *bla<sub>CTX-M-14b</sub>*. *Antimicrob Agents Chemother* 59:1337–1340. <http://dx.doi.org/10.1128/AAC.04631-14>.
  24. Liu H, Wang Y, Wu C, Schwarz S, Shen Z, Jeon B, Ding S, Zhang Q, Shen J. 2012. A novel phenicol exporter gene, *fexB*, found in enterococci of animal origin. *J Antimicrob Chemother* 67:322–325. <http://dx.doi.org/10.1093/jac/dkr481>.
  25. Jensen LB, Garcia-Migura L, Valenzuela AJS, Løhr M, Hasman H, Aarestrup FM. 2010. A classification system for plasmids from enterococci and other Gram-positive bacteria. *J Microbiol Methods* 80:25–43. <http://dx.doi.org/10.1016/j.jmimet.2009.10.012>.
  26. Li X, Alvarez V, Harper WJ, Wang HH. 2011. Persistent, toxin-antitoxin system-independent, tetracycline resistance-encoding plasmid from a dairy *Enterococcus faecium* isolate. *Appl Environ Microbiol* 77:7096–7103. <http://dx.doi.org/10.1128/AEM.05168-11>.
  27. Lam MM, Seemann T, Tobias NJ, Chen H, Haring V, Moore RJ, Ballard S, Grayson LM, Johnson PD, Howden BP, Stinear TP. 2013. Comparative analysis of the complete genome of an epidemic hospital sequence type 203 clone of vancomycin-resistant *Enterococcus faecium*. *BMC Genomics* 14:595. <http://dx.doi.org/10.1186/1471-2164-14-595>.
  28. Moritz EM, Hergenrother PJ. 2007. Toxin-antitoxin systems are ubiquitous and plasmid-encoded in vancomycin-resistant enterococci. *Proc Natl Acad Sci U S A* 104:311–316. <http://dx.doi.org/10.1073/pnas.0601168104>.
  29. Sletvold H, Johnsen PJ, Wikmark OG, Simonsen GS, Sundsfjord A, Nielsen KM. 2010. *Tn1546* is part of a larger plasmid-encoded genetic unit horizontally disseminated among clonal *Enterococcus faecium* lineages. *J Antimicrob Chemother* 65:1894–1906. <http://dx.doi.org/10.1093/jac/dkq219>.
  30. Clewell DB, Weaver KE, Dunny GM, Coque TM, Francia MV, Hayes F. 2014. Extrachromosomal and mobile elements in enterococci: transmission, maintenance, and epidemiology. In Gilmore MS, Clewell DB, Ike Y, Shankar N (ed), *Enterococci: from commensals to leading causes of drug resistant infection*. Massachusetts Eye and Ear Infirmary, Boston, MA.
  31. Wang XM, Li XS, Wang YB, Wei FS, Zhang SM, Shang YH, Du XD. 2015. Characterization of a multidrug resistance plasmid from *Enterococcus faecium* that harbours a mobilized *bcrABDR* locus. *J Antimicrob Chemother* 70:609–611. <http://dx.doi.org/10.1093/jac/dku416>.