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Short report

Vagino-rectal colonization and maternal–neonatal transmission of Enterobacteriaceae producing extended-spectrum β-lactamases or carbapenemases: a cross-sectional study

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SUMMARY

This study sought to determine the prevalence and risk factors for colonization with extended-spectrum β-lactamase-producing Enterobacteriaceae (ESBL-E) and carbapenemase-producing Enterobacteriaceae (CPE) in 815 mothers and 800 newborns using a cross-sectional design; 59 women and 13 neonates were colonized by ESBL-E (prevalence (95% confidence interval): 6.7% (5.2–8.7) and 1.6 (0.7–2.5), respectively). No CPE were found. The most frequent ESBL-E were CTX-M-14 and SHV-12. Vertical transmission occurred in 14% of colonized mothers. The risk factors for colonization were, in mothers: complications in previous pregnancies, more than one urinary tract infection, non-Caucasian ethnicity, and frequently having the main meal outside home; in newborns: colonized mother and vaginal delivery.

Introduction

Antimicrobial resistance is recognized as a public health problem globally [1]. Extended-spectrum β-lactamase-producing Enterobacteriaceae (ESBL-E) are resistant to penicillins and cephalosporins, and frequently also to non-β-lactam drugs. ESBL-E cause a considerable proportion of invasive infections caused by Enterobacteriaceae, and these infections have been associated with worse outcomes than those caused by antibiotic-susceptible strains [2]. In neonates, micro-organisms causing early neonatal sepsis are thought to be mostly vertically transmitted through the birth canal; early neonatal infections caused by ESBL-E may lead to inappropriate empiric therapy. However, data on colonization by ESBL-E in mothers at delivery and on rates of vertical transmission are scarce [3–6]. Whether screening for ESBL-E colonization in mothers should be performed is a matter of controversy [6].

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The objectives of this study were to investigate the prevalence of colonization by ESBL-E in mothers and their neonates, the rate of vertical transmission, and the risk factors associated, in an area with a well-characterized epidemiology of these organisms.

Methods

Design, site, study period and participants

A cross-sectional study in which colonization by ESBL-E or carbapenemase-producing Enterobacteriaceae (CPE) in pregnant women at the time of delivery and their newborns was performed at Hospital Universitario Virgen Macarena, a teaching hospital in Seville, Spain, which serves a population of 450,000 and attends 3600 births per year. The study was conducted from August 2014 until June 2015. The hospital has a very active infection control programme, including surveillance of hand hygiene in the maternity area. All pregnant women who gave birth at the hospital were eligible if attended on predefined random days and offered to participate. No exclusion criteria applied. Informed consent was obtained from participants. The local ethics committee approved the study (code 2124). We followed the STROBE recommendations for reporting observational studies (Supplementary Table S1).

Definitions and data collection

The main outcome variable was colonization by ESBL-E or CPE in mothers and their newborns, defined as isolation of these organisms from the rectal or vaginal swab obtained from mothers or rectal swabs from children. The contributory variables were selected after a literature review and included sociodemographic features, variables related to pregnancy and delivery, and features of the newborns (Supplementary Table S2). Vertical transmission was defined as the isolation of the same pulsotype from the mother and her newborn (see below). Data were collected in a pre-designed questionnaire by interviewing the pregnant women and reviewing the medical charts by trained investigators, blinded to colonization status.

Microbiological studies

Vaginorectal swabs from mothers and rectal swabs from neonates were taken during the first 24 h after delivery and inoculated into 4 mg/L cefotaxime MacConkey agar both directly and after 18 h enrichment with peptone broth. Environmental samples in the maternity area were collected if nosocomial transmission was suspected. All the morphotypes compatible with Enterobacteriaceae were identified by matrix-assisted laser desorption/ionization time-of-flight mass spectrometry. ESBL screening was carried out by using the combination disc test (CDT) on Mueller—Hinton agar with and without 250 mg/L cloxacillin. Confirmation of ESBL genes was conducted by polymerase chain reaction (PCR) and sequencing [7]. The genetic relationship between the isolates determined by *XbaI* pulsed-field gel electrophoresis (PFGE). Isolates with >2 bands' differences were considered clonally unrelated. *Escherichia coli* phylogenetic groups were assigned according to quadruplex PCR for *chuA*, *yjaA*, *TspE4.C2* and *arpA* gene targets. All B2 isolates were screened for belonging to the O25b:H4/ST131 clonal group, using PCR with primers for O25b rfb and allele 3 of the *pabB* gene, and multiplex PCR for phylogroup B23 typing.

Statistical analysis

Rectal colonization by ESBL-E in the general population in our area is 7% [7]. Therefore, ~800 pregnant women should be included at the time of delivery to detect 50—60 colonized patients for whom risk factors were investigated allowing for five or six variables in the final multivariate models.

Univariate analyses were performed by comparing the frequency of colonization in those exposed and not exposed to the different variables studied, with calculation of relative risk (RR) and 95% confidence interval (CI). The χ^2-test or Fisher's exact test was used for categorical variables, Student's *t*-test or Mann—Whitney *U*-test for continuous variables. Multivariate analyses were performed by including variables with $P < 0.1$ in the univariate analysis; a stepwise backward procedure was used to select variables. To evaluate the predictive capacity of the models, the area under the receiver operating characteristic (AUROC) curve and its 95% CI was calculated. Statistical analyses were performed using the statistical package SPPS version 17.0.

Results

Overall, 815 women and 800 neonates were studied. The main characteristics of the participants are shown in Supplementary Table S2.

Prevalence of colonization by ESBL-E and CPE in mothers and newborns in childbirth

Of the 815 women included, 59 were found to be colonized by ESBL-E at delivery (prevalence, 7.2%; 95% CI: 5.6—9.2). Four of the women who had given birth during the same day were colonized by identical isolates of *Klebsiella pneumoniae* producing SHV-12, and were considered to have acquired the micro-organism by nosocomial transmission in the maternity unit; 20 environmental samples including sinks, surfaces and equipment were taken in the maternity area within seven days after detection and all were negative for ESBL-E. No further cases of colonization or infection due to this strain were found. When these women were excluded for the calculation of community-acquired colonization by ESBL-E, the prevalence was 6.7% (95% CI: 5.2—8.7).

Among the 800 neonates studied, 13 were found to be colonized at birth by ESBL-E (prevalence: 1.6%; 95% CI: 0.75—2.5).

No mother or neonate was found to be colonized by CPE.

ESBL-E isolates

Fifty-eight isolates of ESBL-E were obtained from the 55 mothers; 56 were *E. coli* (99.6%), one *K. oxytoca* (1.7%) and one *K. pneumoniae* (1.7%). Three mothers carried two different pulsotypes of *E. coli*. The most frequent type of ESBLs were CTX-M in 45 isolates (77.5%), of which 25 were CTX-M-14, 10

Table I
Univariate and multivariate analyses of the risk of maternal colonization by ESBL-producing Enterobacteriaceae depending on exposure to different risk factors

Variable		Colonized/exposed (%)	RR (95% CI)	*P*-value	Adjusted OR (95% CI)	*P*-value
Age (years)	≤30	24/375 (6.5)	0.90 (0.53–1.51)	0.68		
	>30	31/436 (7.1)				
Ethnic group	Not caucasian	12/70 (17.1)	2.95 (1.63–5.35)	0.001	3.45 (1.67–7.11)	0.001
	Caucasian	43/741 (5.8)				
Time of residence in Spain (months)	≤24	3/15 (20)	3.06 (1.07–8.71)	0.07		
	>24	52/796 (6.5)				
Educational level	Primary or lower	21/245 (8.6)	1.42 (0.84–2.40)	0.18		
	Secondary or higher	34/566 (6)				
Cohabitants at home	1 or 2	23/375 (7.1)	1.07 (0.64–1.80)	0.78		
	>2	32/486 (6.6)				
Travel abroad during pregnancy	Yes	12/131 (9.2)	1.45 (0.78–2.67)	0.23		
	No	43/680 (6.3)				
Main meal outside home last month (days)	>15	16/116 (13.8)	2.46 (1.42–4.25)	0.01	2.91 (1.52–5.55)	0.001
	≤15	39/695 (5.6)				
Multigravida	Yes	32/474 (6.8)	1.01 (0.60–1.69)	0.96		
	No	23/337 (6.8)				
Multiparous	Yes	22/345 (6.4)	1.11 (0.65–1.87)	0.69		
	No	33/466 (7.1)				
Previous abortions	Yes	14/172 (8.1)	1.27 (0.70–2.27)	0.42		
	No	41/639 (6.4)				
Previous caesarean section	Yes	4/80 (5)	0.71 (0.26–1.93)	0.50		
	No	51/731 (7)				
Complications in previous pregnancies[b]	Yes	6/42 (14.3)	2.24 (1.01–4.92)	0.051	2.79 (1.08–7.17)	0.03
	No	49/769 (6.4)				
Multiple gestation	Yes	0/18 (0)	–	0.62		
	No	55/793 (6.9)				
Advanced reproductive therapy	Yes	2/21 (9.5)	1.42 (0.37–5.43)	0.64		
	No	53/790 (6.7)				
Hypertension	Yes	0/10 (0)	–	1[a]		
	No	55/801 (6.9)				
Gestational hypertension ($N = 801$)	Yes	4/31 (12.9)	1.94 (0.75–5.05)	0.15		
	No	51/770 (6.6)				
Pre-eclampsia	Yes	1/5 (20)	2.98 (0.50–1.75)	0.23		
	No	54/806 (6.7)				
Pre-gestational diabetes	Yes	0/7 (0)	–	1[a]		
	No	55/804 (6.8)				
Gestational diabetes ($N = 804$)	Yes	3/36 (8.3)	1.23 (0.40–3.75)	0.72[a]		
	No	52/768 (6.8)				
Renal insufficiency	Yes	0/1 (0)	–	1[a]		
	No	55/810 (6.8)				
Liver disease	Yes	0/4 (0)	–	1[a]		
	No	55/807 (6.8)				
Cardiopathy	Yes	0/4 (0)	–	1[a]		
	No	55/807 (6.8)				
Inmunosuppressant drugs	Yes	0/4 (0)	–	1[a]		
	No	55/807 (6.8)				
Urinary tract infection	Yes	16/138 (11.6)	2.0 (1.15–3.47)	0.02		
	No	39/673 (5.8)				
Urinary tract infections, >1 episode	Yes	14/92 (15.2)	2.66 (1.15–4.69)	0.001	2.73 (1.38–5.37)	0.004
	No	41/719 (5.7)				
Antibiotics during pregnancy	Yes	16/170 (9.4)	1.54 (0.88–2.7)	0.12		
	No	39/641 (6.1)				
Fosfomycin use during pregnancy	Yes	8/98 (8.2)	1.23 (0.60–2.54)	0.56		
	No	47/713 (6.6)				

(*continued on next page*)

Table I (*continued*)

Variable		Colonized/exposed (%)	RR (95% CI)	*P*-value	Adjusted OR (95% CI)	*P*-value
β-Lactams during pregnancy	Yes	8/91 (8.8)	1.34 (0.65—2.76)	0.41		
	No	47/720 (6.5)				
Hospitalization during pregnancy	Yes	1/48 (2.1)	0.29 (0.04—2.08)	0.24		
	No	54/763 (7.1)				
Amenorrhoea (total weeks)						
>38	Yes	53/764 (6.9)	0.62 (0.24—1.63)	0.31		
	No	4/36 (11.1)				
>41	Yes	11/158 (7)	1.03 (0.54—1.95)	0.92		
	No	44/653 (6.7)				
Premature rupture of membranes	Yes	35/526 (6.7)	1.05 (0.62—1.79)	0.84		
	No	20/258 (7)				
Streptococcus agalactiae carrier ($N = 757$)	Yes	9/133 (6.8)	0.95 (0.48—1.91)	0.90		
	No	44/624 (7.1)				
Intrapartum antibiotics	Yes	25/362 (6.9)	1.03 (0.01—1.72)	0.89		
	No	30/449 (6.7)				
Length of labour						
>12 h	Yes	44/633 (6.6)	0.89 (0.47—1.68)	0.72		
	No	11/148 (7.4)				
>8 h	Yes	18/257 (7)	1.04 (0.62—1.80)	0.86		
	No	37/554 (6.7)				
Epidural anaesthesia	Yes	44/681 (6.5)	0.76 (0.40—1.43)	0.40		
	No	11/130 (8.5)				
Use of enema for delivery	Yes	1/16 (6.2)	0.91 (0.13—6.25)	1[a]		
	No	54/795 (6.8)				
Urinary catheterization during labour	Yes	21/276 (7.6)	1.19 (0.71—2.02)	0.50		
	No	34/535 (6.4)				
Induced labour	Yes	13/154 (8.4)	1.32 (0.72—2.39)	0.36		
	No	42/657 (6.4)				
Caesarean section	Yes	13/137 (9.5)	1.52 (0.84—2.76)	0.16		
	No	42/674 (6.2)				
Vaginal tear ($N = 674$)	Yes	20/357 (5.6)	0.80 (0.44—1.45)	0.47		
	No	22/317 (6.9)				
Vaginal tear grade III or IV ($N = 674$)	Yes	1/23 (4.3)	0.69 (0.09—4.80)	1[a]		
	No	41/651 (6.3)				
Instrumental delivery ($N = 674$)	Yes	6/113 (5.3)	0.82 (0.35—1.91)	0.65		
	No	36/561 (6.4)				
Episiotomy ($N = 674$)	Yes	13/235 (5.5)	0.83 (0.44—1.57)	0.58		
	No	29/439 (6.6)				

ESBL, extended-spectrum β-lactamase; RR, relative risk; OR, odds ratio; CI, confidence interval.
The four women with putative nosocomial colonization were excluded from this analysis.
[a] Fisher's exact test.
[b] Includes: ectopic pregnancy, dead fetus, oligohydramnios, pre-eclampsia.

CTX-M-1, four CTX-M-15, and six other types. SHV-12 were produced by 13 isolates (22.4%); TEM-52 was produced by one isolate (1.78%); one isolate produced CTX-M-1 and SHV-12. Among *E. coli*, the most frequent phylogenetic group was A (22 isolates, 39.3%), followed by B1 (19, 33.9%), D (eight, 14.3%) and B2 (seven; 12.5%). None of the B2 *E. coli* isolates produced CTX-M-15 or belonged to O25b/ST131. As described above, four additional mothers were colonized by clonally related SHV-12-producing *K. pneumoniae*.

All the 13 colonized neonates had an ESBL-producing *E. coli*; one of them was also colonized by ESBL-producing *K. pneumoniae*. The enzymes produced were of the CTX-M family in seven (53.8%; five were CTX-M-14) and SHV-12 in six (46.2%). Among the *E. coli* isolates, seven belonged to phylogroup A, three to D, two to B2, and one to B1.

Analysis of vertical transmission of ESBL-E

The mothers of 10 out of the 13 ESBL-E colonized neonates (76.9%) were also colonized at the time of delivery. The isolates from mothers and neonates of eight out of the 10 mother—newborn pairs both colonized by ESBL-E were clonally related by PFGE and produced the same ESBL (CTX-M-14 in five pairs, SHV-12 in two and CTX-M-1 in one) and constituted episodes of confirmed vertical transmission. The rate of vertical transmission among colonized mothers was 14.0% (8/57; 95% CI: 7.0—25.5%), and among all studied mother—newborn pairs was 1.0% (8/800; 95% CI: 0.4—2.0%). As for the two pairs with non-clonally related isolates, one of the mothers was colonized by CTX-M-14-producing *E. coli* and her newborn by *E. coli* and *K. pneumoniae* both producing SHV-12, and the other mother

Table II
Univariate analysis of the risk of newborn colonization by ESBL-producing Enterobacteriaceae depending on exposure to different risk factors

Variable		Colonized/exposed (%)	RR (95% CI)	*P*-value
Sex	Male	5/430 (1.2)	1.85 (0.61–5.64)	0.26
	Female	8/370 (2.2)		
Birth weight				
<2500 g	Yes	0/41 (0)	–	1[a]
	No	13/759 (1.7)		
>4000 g	Yes	1/45 (2.2)	1.39 (0.18–1.05)	0.53[a]
	No	12/755 (1.6)		
Apgar score (min)				
1	≥8	13/760 (1.7)	–	1[a]
	<8	0/40 (0)		
5	≥8	13/799 (1.6)	–	1[a]
	<8	0/1 (0)		
10	≥8	13/799 (1.6)	–	1[a]
	<8	0/1 (0)		
Need for respiratory secretions aspiration	Yes	3/241 (1.2)	0.69 (0.19–2.50)	0.764[a]
	No	10/559 (1.8)		
Gastric lavage	Yes	0/43 (0)	–	1[a]
	No	13/757 (1.7)		
Neonatology ward admission	Yes	0/5 (0)	–	1[a]
	No	13/795 (1.6)		
Maternal age (years)	≤30	6/367 (1.6)	1.01 (0.34–2.98)	0.98
	>30	7/433 (1.6)		
Time of residence in Spain (months)	≤24	0/14 (0)	–	1[a]
	>24	13/786 (1.6)		
Cohabitants at home	1 or 2	6/332 (1.9)	1.27 (0.43–3.75)	0.66
	>2	7/478 (1.5)		
Healthcare professional	Yes	1/58 (1.7)	1.06 (0.14–8.06)	1[a]
	No	12/742 (1.6)		
Travel abroad during pregnancy	Yes	1/126 (0.8)	0.44 (0.05–3.40)	0.70[a]
	No	12/674 (1.8)		
Main meal outside home last month (days)	>15	3/114 (2.6)	1.80 (0.50–6.45)	0.41[a]
	≤15	10/686 (1.5)		
Multigravida	Yes	7/467 (1.5)	0.83 (0.28–2.45)	0.73
	No	6/333 (1.8)		
Multiparous	Yes	5/338 (1.5)	0.85 (0.28–2.59)	0.78
	No	8/462 (1.7)		
Previous abortions	Yes	3/171 (1.8)	1.10 (0.30–3.96)	1[a]
	No	10/629 (1.6)		
Previous caesarean section	Yes	2/80 (2.5)	1.63 (0.36–7.24)	0.37[a]
	No	11/720 (1.5)		
Complications in previous pregnancies	Yes	1/41 (2.4)	1.54 (0.20–1.16)	0.49[a]
	No	1/759 (1.6)		
Advanced reproductive therapy	Yes	1/25 (4)	2.58 (0.34–19.23)	0.34
	No	12/775 (1.5)		
Hypertension	Yes	0/10 (0)	–	1[a]
	No	13/790 (1.6)		
Gestational hypertension	Yes	0/32 (0)	–	1[a]
	No	13/768 (1.7)		
Pre-eclampsia	Yes	0/5 (0)	–	1[a]
	No	13/795 (1.6)		
Diabetes	Yes	0/7 (0)	–	1[a]
	No	13/787 (1.6)		
Gestational diabetes ($N = 793$)	Yes	2/36 (5.6)	3.81 (0.87–16.60)	0.11[a]
	No	11/757 (1.5)		
Renal insufficiency	Yes	0/1 (0)	–	1[a]
	No	13/799 (1.6)		

(*continued on next page*)

Table II (*continued*)

Variable		Colonized/exposed (%)	RR (95% CI)	*P*-value
Liver disease	Yes	0/4 (0)	–	1[a]
	No	13/796 (1.6)		
Cardiopathy	Yes	0/4 (0)	–	1[a]
	No	13/796 (1.6)		
Inmunosuppressant drugs	Yes	0/4 (0)	–	1[a]
	No	13/796 (1.6)		
Urinary tract infection	Yes	4/137 (2.9)	2.15 (0.67–6.89)	0.25[a]
	No	9/663 (1.4)		
Urinary tract infections, >1 episode	Yes	3/92 (3.3)	2.30 (0.64–8.26)	0.18[a]
	No	10/708 (1.4)		
Antibiotics during pregnancy	Yes	4/167 (2.4)	1.68 (0.52–5.40)	0.376[a]
	No	9/633 (1.4)		
Antibiotics during last 6 months	Yes	3/147 (2)	1.33 (0.37–4.78)	0.71[a]
	No	10/653 (1.5)		
Use of fosfomycin during pregnancy	Yes	4/97 (4.1)	3.22 (1.01–10.30)	0.61[a]
	No	9/703 (1.3)		
β-Lactams during pregnancy	Yes	3/92 (3.3)	7.99 (0.64–8.26)	0.18[a]
	No	10/708 (1.4)		
More than one antibiotic treatment	Yes	2/24 (8.3)	5.88 (1.37–25.00)	0.05[a]
	No	11/776 (1.4)		
Hospitalization during pregnancy	Yes	1/47 (2.1)	1.33 (0.17–10.10)	0.54[a]
	No	12/753 (1.6)		
Amenorrhoea (total weeks)				
>38	Yes	12/764 (1.6)	0.56 (0.07–4.23)	0.45[a]
	No	1/36 (2.8)		
>41	Yes	1/155 (0.6)	0.34 (0.04–2.64)	0.48[a]
	No	12/645 (1.9)		
Premature rupture of membranes	Yes	6/282 (2.1)	1.57 (0.48–5.02)	0.39[a]
	No	7/518 (1.4)		
Streptococcus agalactiae carrier ($N = 762$)	Yes	3/129 (2.3)	1.47 (0.41–5.26)	0.47[a]
	No	10/633 (1.6)		
Mother carrier of ESBL-E	Yes	10/57 (17.5)	43.47 (12.34–142.85)	<0.001
	No	3/743 (0.4)		
Intrapartum antibiotics	Yes	7/354 (2)	1.47 (0.49–4.32)	0.48
	No	6/446 (1.4)		
Length of labour				
>12 h	Yes	2/147 (1.4)	0.80 (0.18–3.61)	1[a]
	No	11/653 (1.7)		
>8 h	Yes	6/258 (2.3)	1.80 (0.61–5.29)	0.36[a]
	No	7/542 (1.3)		
Epidural anaesthesia	Yes	11/674 (1.6)	1.02 (0.23–4.58)	1[a]
	No	2/126 (1.6)		
Use of enema for delivery	Yes	0/16 (0)	–	1[a]
	No	13/784 (1.7)		
Urinary catheterization during labour	Yes	8/533 (1.5)	0.80 (0.26–2.42)	0.76[a]
	No	5/267 (1.9)		
Induced labour	Yes	3/156 (1.9)	1.23 (0.34–4.44)	0.72[a]
	No	10/644 (1.6)		
Vaginal delivery	Yes	13/670 (1.9)	–	0.14[a]
	No	0/130 (0)		
Vaginal tear	Yes	7/354 (2)	1.41 (0.35–3.06)	0.94
	No	6/316 (1.9)		
Vaginal tear, grade III or IV	Yes	1/25 (4)	2.15 (0.29–15.87)	0.39[a]
	No	12/645 (1.9)		
Instrumental delivery	Yes	4/116 (3.4)	2.12 (0.66–6.75)	0.25[a]
	No	9/554 (1.6)		
Episiotomy	Yes	5/237 (2.1)	1.14 (0.37–3.44)	0.77[a]
	No	8/433 (1.8)		

ESBL-E, extended-spectrum β-lactamase-producing Enterobacteriaceae.
[a] Fisher's exact test.

(who was one of the four affected by the nosocomial transmission episode) was colonized by *K. pneumoniae* producing SHV-12 and the neonate by *E. coli* producing SHV-12.

Risk factors of maternal and newborn colonization by ESBL-E

The univariate and multivariate analyses of risk factors for community colonization by ESBL-E in mothers at delivery are shown in Table I. The AUROC of the multivariate model showed moderate predictive ability (0.69; 95% CI: 0.61—0.76).

The univariate risk factors for colonization with ESBL-E in newborns are shown in Table II. The only variable associated with colonization in the multivariate analysis was being born to a colonized mother (adjusted odds ratio: 57.5; 95% CI: 15.1—218.1; $P < 0.001$). Since all the colonized neonates had been born vaginally, a multivariate analysis was also performed only with the neonates born in this way; none of the variables was associated with neonatal colonization in adjusted models. Therefore, maternal colonization and vaginal delivery are the key variables for vertical transmission.

Discussion

In this study, prevalence of ESBL-E colonization in mothers and newborns at birth was 6.7% and 1%, respectively, and vertical transmission rate of ESBL-E from colonized mothers was 14%. Also, some risk factors for colonization were identified.

A probable episode of nosocomial transmission of ESBL-producing *K. pneumoniae* in mothers was identified. Since no environmental source was found, it may be that the spread occurred through cross-transmission, despite >80% global adherence to hand hygiene in the maternity area in a previous measurement.

The prevalence of colonization in pregnant women found in this study is similar to that of the general population of our area [7]. In previous studies performed in other areas, the prevalence of colonization by ESBL-E in pregnant women also mostly reflected the local epidemiology of ESBL-E. Prevalence ranged from 2.4% to 11.1% in studies performed in France, Germany and Norway, whereas it was 15% in India [3—5,8]. This suggests no additional risk or protective effect of pregnancy for ESBL-E colonization compared with the general population. Likewise, the distribution of the different types of ESBL in pregnant women in our study is also a reflection of the ESBLs circulating in our area [7].

Some risk factors for colonization by ESBL-E in pregnant women were identified in this study: having suffered more than one episode of urinary tract infection may be related to the use of antibiotics; complications in a previous pregnancy are probably a proxy for other variables such as healthcare contact and underlying conditions; and the non-Caucasian ethnic group may be related to household transmission from relatives travelling to their countries of origin. Finally, having their meal frequently outside home during the last month would suggest a highest risk of acquisition related to food, but we did not collect detailed information about this. We found only two previous studies investigating the risk factors for carrier status during pregnancy. Rettedal *et al.* found higher risk in Black and Asian women [5]. Pathak *et al.* found exposure to antibiotics or recent hospitalization as risk factors [8]. The fact that the multivariate model in our study only showed a moderate predictive ability for observed data suggests that there are risk factors that we did not identify or that ESBL-E risk has a random pattern.

Regarding the prevalence in neonates, there are highly variable rates in the literature ranging from 2% to 33% [3,4,9,10], again probably reflecting differences in the local epidemiology of ESBL-E. Regarding the rate of vertical transmission of ESBL-E, there are few data in the literature, and most studies report isolated cases. In a study performed in Norway, Rettedal *et al.* found a vertical transmission rate of 35.7% for carrier mothers with vaginal delivery [5]. Data are also scarce regarding risk factors for neonatal colonization by ESBL-E at birth. In our study, maternal colonization and vaginal delivery were the critical factors. Duman *et al.* found also that antibiotic use in the newborn or mother and very low weight in the neonate increased the risk [10]. Denkel *et al.* also found that colonization of the mother was a risk factor, but found many cases in caesarean deliveries [6].

This study has several limitations. First, the work was carried out in a single centre and may not be extrapolated to areas with a different epidemiology. Some risk factors may not have been studied, even though we included all potential exposures of interest as found in the literature. The sample size was small. The sensitivity of carrier detection techniques using phenotypic techniques was limited. Finally, the study was performed in 2014—2015, and we cannot discount the possibility that the situation might be different today, especially with regard to CPE.

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Conflict of interest statement
None declared.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2018.09.010.

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