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ORIGINAL ARTICLE

Current status of post-operative infections due to antimicrobial-resistant bacteria after digestive tract surgery in Japan: Japan Postoperative Infectious Complications Survey in 2015 (JPICS'15)

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Abstract

Purpose We herein report the findings of the Japan Postoperative Infectious Complication Survey in 2015 (JPICS'15), which evaluated the rate of post-operative infections and colonization due to antimicrobial-resistant (AMR) bacteria after digestive tract surgery.

Methods This survey by the Japan Society of Surgical Infection included patients undergoing digestive tract surgery at 28 centers between September 2015 and March 2016. Data included patient background characteristics, type of surgery, contamination status, and type of post-operative infections, including surgical site infections (SSIs), remote infections (RIs), and colonization.

Results During the study period, 7,565 surgeries (of 896 types) were performed; among them, 905 cases demonstrated bacteria after digestive tract surgery. The survey revealed that post-operative infections or colonization by AMR bacteria occurred in 0.9% of the patient cohort, constituting 7.5% of post-operative infections, including 5.6% of SSIs and 1.8% of RIs. Extended-spectrum β-lactamase-producing *Enterobacteriaceae* and methicillin-resistant *Staphylococcus aureus* were the predominant AMR bacteria isolated from patients after digestive tract surgery. Patients infected with AMR bacteria had a poor prognosis.

Conclusion Our results reveal that 7.5% of the post-operative infections were due to AMR bacteria, indicating the need for antibacterial coverage against AMR bacteria in patients with critical post-operative infections.

Keywords Surgical site infection · Remote infection · Post-operative infection · Digestive tract surgery

Introduction

Post-operative infections are an important category of healthcare-associated infections (HAIs) with a substantial impact on patient morbidity and mortality [1, 2]. In addition, they increase healthcare costs and hospital re-admissions [1, 3–7]. Among the post-operative infections following major digestive tract surgery, surgical site infections (SSIs) are the most common. They represent 38% of all post-operative complications [8], with incidence rates ranging between 4.0 and 24% [6, 9–15].

Owing to an increase in the global incidence of antimicrobial-resistant (AMR) bacteria and the emergence of community-acquired infections, infections and colonization due to antimicrobial-resistant (AMR) bacteria have also become

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an increasingly significant problem [15–19]. Previous studies have reported that Gram-positive cocci are the most frequent bacteria found in post-operative infections [1, 20, 21]. Among them, methicillin-resistant *Staphylococcus aureus* (MRSA) is highly prevalent. In addition, Gram-negative bacilli (GNB) are becoming more important as etiologic agents of post-operative infections [22]. Extended-spectrum β-lactamase (ESBL)-producing *Enterobacteriaceae* has also increased in many regions of the world, and in some regions, and is the most frequent isolate of HAIs [23]. Although less frequent as causative agents, other multi-antibacterial-resistant GNB, such as carbapenem-resistant *Pseudomonas aeruginosa* (IPM-RP) and vancomycin-resistant *Enterococci* (VRE), are being increasingly implicated in post-operative infections, especially among severely ill patients [24, 25].

Data on the likely origin of the causative bacteria are needed to refine prevention strategies and implement quality-improvement interventions [26–28]. Reducing the rate of post-operative infections due to AMR bacteria requires data collection, analyses, and feedback [29]. Therefore, investigations on the prevalence of AMR bacterial infections and colonization after digestive tract surgery are important for improving the understanding among healthcare workers regarding this current issue.

We herein present the findings of the Japan Postoperative Infectious Complications Survey, 2015 (JPICS'15), which focused on the relationship between post-operative infections after digestive tract surgery, and the rates of specific post-operative AMR bacterial infections and colonization.

Methods

Analysis plan

This survey, administered via an online system, was conducted by the Japan Society for Surgical Infection and included patients at 28 centers across Japan, between September 2015 and March 2016. Data on individual surgical cases were collected. Trained and experienced infection preventionists retrospectively entered data collected from patients. The study protocol was prepared by a working group and was accepted by the governing board of the Japan Society for Surgical Infection. Individual study centers were responsible for obtaining ethical approval. All patient data were reported anonymously to the study database.

Patients' data

The following patient information was stored in the database: treating hospital, age, sex, type of digestive tract surgical procedure, procedure date and duration, contamination status, the presence or absence of colonization before digestive tract surgery, isolated bacteria after digestive tract surgery, and prognosis during hospitalization. In descending order of cleanliness, the contamination status was categorized as class I (clean), class II (clean contaminated), class III (contaminated), and class IV (dirty infected). This was based on the surgical condition of the wound according to the Center for Disease Control and Prevention wound classification system [30]. The surgical procedures included esophageal surgery, gastrointestinal surgery, colorectal surgery, liver surgery, biliary surgery, cholecystectomy, pancreatic surgery, appendectomy, hernia surgery, and surgery for acute peritonitis. The surgical procedures were also categorized by the approach as either open or endoscopic.

Diagnostic criteria

Post-operative infections were categorized as SSIs and remote infections (RIs). SSIs were classified as (i) incisional SSIs (ii) organ SSIs (iii) space SSIs (with no anastomotic leakage and no digestive tract fistulas), and (iv) space SSIs-2 (with anastomotic leakage and/or digestive tract fistulas). The diagnosis of incisional and organ/space SSIs was made according to the guidelines of the National Healthcare Safety Network of the Center for Disease Control and Prevention [30].

RIs were classified as (i) respiratory tract infections (RTI), (ii) urinary tract infections (UTI), (iii) antibiotic-associated diarrhea, (iv) catheter-related bloodstream infections, (v) drain infections, and (vi) bacteremia of unknown origin. The diagnosis of bacterial infection was based on the isolation of bacteria from specimens with inflammatory findings including high fever, elevated white blood cell counts, and elevated C-reactive protein levels. Bacterial colonization was defined as the presence of low-volume bacteria, such as more than 1 + on a qualitative analysis, in the absence of any inflammatory findings.

Prognostic criteria

The post-operative prognosis for individual cases of digestive tract surgery was scored on a scale of 0–5, which considered the individual performance status in relation to the premorbid state. The scoring criteria were as follows: 0, the patient is able to perform social activities as in the premorbid state without any regulation (completely healthy); 1, the patient has minor symptoms but is able to work and do light labor and sedentary work, such as simple housework and deskwork; 2, the patient is able to walk and perform activities of self-care but needs occasional assistance and is capable of light labor, spending less than 50% of the day in bed; 3, the patient is capable of self-care but needs considerable assistance and spends more than 50% of the day in bed; 4,

the patient is incapable of self-care and spends the entire day in bed; 5, the patient is dead.

Identification of bacteria

This analysis focused on the incidence of the following AMR bacteria: (i) MRSA (ii) ESBL-producing *Enterobacteriaceae* (iii) imipenem-resistant *Pseudomonas aeruginosa* (IPM-RP) (iv) vancomycin-resistant *Enterococci* (VRE) (v) multidrug-resistant GNB (MDR-GN), and (vi) multidrug-resistant *P. aeruginosa* (MDRP). The identification and susceptibility tests for the six bacteria of interest were conducted in the individual participating medical facilities. All isolates were tested for susceptibility using the broth microdilution method, as described by the Clinical and Laboratory Standards Institute (CLSI) [31]. For the purposes of this study, we included all surgical specimens (wounds, abscesses, pus aspirates, or tissues) cultured at the microbiology laboratory during the study period, irrespective of surgical type.

Statistical analyses

Statistical analyses were performed using Fisher's exact test or the χ^2 test for categorical data. Categorical variables were presented as numbers, and continuous variables were presented as medians with ranges. A probability (P) value of < 0.05 was considered to be statistically significant. All statistical analyses were performed using the JMP software package, ver.10.0 (SAS, Tokyo, Japan).

Results

Detection of AMR bacteria after digestive tract surgery

During the study period, 7,565 surgeries (896 surgical types) were performed. Among them, AMR bacteria were identified as the causative organism of post-operative infections or colonization in 66 cases (0.9%) (Table 1). Overall, MRSA was shown to be the most prevalent of AMR bacteria causing post-operative infections or colonization, accounting for 0.5% ($n = 35$) of the isolates. ESBL-producing *Enterobacteriaceae* were the second-most prevalent organisms ($n = 21$, 0.3%), followed by MDR-GN ($n = 6$, 0.1%), and IMP-RP ($n = 4$, 0.1%). VRE and MDRP were not isolated from any patient during the study period. A total of 905 patients showed evidence of bacteria in specimens collected after surgery; post-operative infections or colonization with AMR bacteria accounted for 7.3% of these cases. MRSA were the most prevalent bacteria, accounting for 3.9% of the isolates, followed by ESBL-producing *Enterobacteriaceae* (2.3%), MDR-GN (0.7%), and IMP-RP (0.4%).

Detection of AMR bacteria after digestive tract surgery according to sex

Among the 7,565 cases with evidence of bacteria after surgery, 613 (8.1%) and 292 (3.9%) patients were male and female, respectively (Table 1). In the 905 cases with evidence of post-operative infection or colonization, 67.7% of patients were male. Among all cases of post-operative infection or colonization related to AMR bacteria, 44 (7.2%) and 22 (7.5%) occurred in male and female patients, respectively ($p = 0.873$). MRSA were the most prevalent bacteria in males, accounting for 4.2% ($n = 26$) of the isolates, irrespective of the type of surgery. ESBL-producing *Enterobacteriaceae* were the second-most prevalent bacteria ($n = 11$, 1.8%) in males, followed by MDR-GN ($n = 4$, 0.7%), and IMP-RP ($n = 3$, 0.5%). Conversely, ESBL-producing *Enterobacteriaceae* were the most prevalent bacteria in female patients, accounting for 3.4% ($n = 10$) of the isolates. MRSA were the second-most prevalent bacteria ($n = 9$, 3.1%) in females, followed by MDR-GN ($n = 2$, 0.7%), and IMP-RP ($n = 1$, 0.3%).

Detection of AMR bacteria after digestive tract surgery according to age

In the 905 cases of post-operative infection or colonization, the number of patients who were < 40 years old, 40–49 years old, 50–59 years old, 60–69 years old, 70–79 years old, and ≥ 80 years old were 37 (4.1%), 58 (6.4%), 97 (10.7%), 261 (28.8%), 302 (33.4%), and 150 (16.6%), respectively (Table 1). Among them, 7.8% ($n = 63$) patients showed evidence of post-operative infection or colonization with AMR bacteria. The frequency of isolation of AMR bacteria was 2.7%, 3.4%, 15.5%, 7.7%, 6.3%, and 6.0% in patients < 40 years old, 40–49 years old, 50–59 years old, 60–69 years old, 70–79 years old, and ≥ 80 years old. In those ≥ 70 years old ($n = 452$), the frequency of isolation of AMR bacteria was 6.2% ($n = 28$). Patients ≤ 69 years old ($n = 453$) showed similar frequencies of isolation of AMR bacteria (8.4%) to those > 69 years old ($p = 0.204$). Among them, patients 50–59 years old showed the highest frequency of isolation of AMR bacteria, accounting for 15.5% ($n = 15$) of the 97 cases with evidence of bacteria. MRSA were the most prevalent bacteria ($n = 9$, 9.3%), followed by ESBL-producing *Enterobacteriaceae* ($n = 4$, 4.1%), and MDR-GN ($n = 2$, 2.1%).

Table 1 Detection of AMR bacteria after digestive surgeries and patients' background characteristics

	Cases (*n*)						
	Total	ESBL	MRSA	VRE	MDRP	MDR-GN	IPM-RP
Cases (total)	905[a]	21	35	0	0	6	4
Number of centers	28	14	17	0	0	4	4
Sex (M/F)	613/292	11/10	26/9	0/0	0/0	4/2	3/1
Age (years)							
≤30	37	0	1	0	0	0	0
40–49	58	1	1	0	0	0	0
50–59	97	4	9	0	0	2	0
60–69	261	5	12	0	0	1	2
70–79	302	7	10	0	0	1	1
≥80	150	4	2	0	0	2	1
Pollution degree[b]							
Class I	27	2	0	0	0	0	0
Class II	735	16	27	0	0	6	3
Class III	63	1	4	0	0	0	0
Class IV	79	2	4	0	0	0	1
Detection site[c]							
Pharynx	8	0	1	0	0	0	0
Respiratory tract	18	1	4	0	0	0	0
Urine	7	1	0	0	0	0	0
Feces	15	3	1	0	0	2	1
Others	117	3	4	0	0	0	0
Not detected	740	13	25	0	0	4	3

MRSA methicillin-resistant *Staphylococcus aureus*, *ESBL* extended-spectrum β-lactamase-producing *Enterobacteriaceae*, *IPM-RP* imipenem-resistant *Pseudomonas aeruginosa*, *VRE* vancomycin-resistant *Enterococci*, *MDR-GN* multidrug-resistant Gram-negative bacteria, *MDRP* multidrug-resistant *P. aeruginosa*

[a]The number of surgical cases from which any bacteria were isolated after digestive surgeries

[b]Categorized according to the Center for Disease Control and Prevention wound classification system [30]

[c]Detection sites where any bacteria were isolated before digestive surgeries

Detection of AMR bacteria after digestive tract surgery according to contamination status

Among all patients with isolated bacteria ($n=905$), the contamination status was categorized as class I, II, III, and IV in 27 (3.0%), 735 (81.2%), 63 (7.0%), and 79 (8.7%) patients, respectively (Table 1). Those with a class IV contamination status had the highest infection or colonization rates with AMR bacteria (8.9%; $n=7$), followed by those in classes III (7.9%; $n=5$), I (7.4%; $n=2$), and II (7.1%; $n=52$). MRSA were the most prevalent bacteria, accounting for 5.1% ($n=4$) of the isolates. ESBL-producing *Enterobacteriaceae* were the second-most prevalent organisms ($n=2$, 2.5%), followed by IMP-RP ($n=1$, 1.3%).

Detection of AMR bacteria after digestive tract surgery according to pre-operative colonization status

Some patients were found to have colonization before their surgery (2.2% of all cases, $n=165$). In them, bacteria were isolated from different sites, including the pharynx ($n=8$), respiratory tract ($n=18$), urine ($n=7$), stool ($n=15$), and other sites ($n=117$) (Table 1). The other patients ($n=740$) either demonstrated no evidence of colonization or did not undergo testing with bacterial cultures prior to surgery. Patients with pre-operative colonization with bacteria in the pharynx, respiratory tract, urine, and stool prior to surgery, had AMR bacteria-related post-operative infections

or colonization in 6.0%–46.7% cases; the numbers of these patients, according to site, were as follows: pharynx in 12.5% ($n=1$), respiratory tract in 27.8% ($n=5$), urine in 14.3% ($n=1$), stool in 46.7% ($n=7$), and other sites in 6.0% ($n=7$). Patients with pre-operative evidence of bacterial colonization in the stool showed the highest frequency of AMR bacteria detection after digestive tract surgery. These values were higher than the total frequency of detection of AMR bacteria (0.9%). MRSA were the most prevalent bacteria, accounting for 6.1% ($n=10$) of the isolates. ESBL-producing *Enterobacteriaceae* were the second-most prevalent organisms ($n=8$, 4.8%), followed by MDR-GN ($n=2$, 1.2%), and IMP-RP ($n=1$, 0.6%).

Detection of AMR bacteria after digestive tract surgery and SSIs

The types of post-operative infection are summarized in Table 2. We identified 816 (10.8%) post-operative infections across 7565 surgeries (bacteria were demonstrated in 90.2%). Overall, the cases of post-operative infection included 674 cases of SSIs (74.5%) and 228 cases of RIs (25.2%). Among the SSI cases, incisional SSI accounted for 40.1% ($n=270$) cases, followed by space SSI-2 (35.3%; $n=238$), space SSI (with no anastomotic leakage and no digestive tract fistulas) (18.2%; $n=123$), and organ infections (6.4%; $n=43$). MRSA and ESBL-producing *Enterobacteriaceae* were the predominantly isolated bacteria. Among patients with incisional SSIs, MRSA were the most prevalent bacteria, accounting for 4.8% ($n=13$) of the isolates, followed by ESBL-producing *Enterobacteriaceae* (1.5%; $n=4$), IMP-RP (0.7%; $n=2$), and MDR-GN (0.4%; $n=1$). Among patients with space SSIs (with no anastomotic leakage and no digestive tract fistulas), MRSA were the most prevalent bacteria, accounting for 3.3% ($n=4$) of the isolates, followed by ESBL-producing *Enterobacteriaceae* (1.6%; $n=2$), IMP-RP ($n=0$) and MDR-GN ($n=0$). Among patients with space SSI-2 (with anastomotic leakage and/or digestive tract fistulas), ESBL-producing *Enterobacteriaceae* were the most prevalent bacteria, accounting for 3.8% ($n=9$) of the isolates, followed by MRSA (2.1%; $n=5$), MDR-GN (1.3%; $n=3$), and IMP-RP (0.4%; $n=1$). Among the patients with organ SSIs, MRSA and ESBL-producing *Enterobacteriaceae* were both demonstrated in a single case (2.3%; $n=1$) (Table 2).

Detection of AMR bacteria after digestive tract surgery and RIs

Among the RIs, RTIs were the most common (34.2%, $n=78$), followed by UTIs (26.3%, $n=60$), catheter-related infections (19.3%, $n=44$), bacteremia of unknown cause (10.5%, $n=24$), drain-related and organ infections (8.8%, $n=20$), and antibiotic-associated colitis (namely MRSA enteritis; 0.9%, $n=2$) (Table 2). MRSA were the predominantly isolated bacteria (4.8%; $n=11$), followed by ESBL-producing *Enterobacteriaceae* (1.3%; $n=3$), and IPM-RP (0.4%; $n=1$). However, no MDR-GN were detected among

Table 2 AMR bacteria detected after digestive surgeries among SSI and RI patients

	Cases (*n*)				
	Total[a]	ESBL	MRSA	MDR-GN	IPM-RP
Cases (total)	905[a]	21	35	6	4
Post-operative infection	816	19	34	4	4
SSIs					
Incisional SSI	270	4	13	1	2
Organ infection	43	1	1	0	0
Space infection (without anastomotic and digestive system fistula)	123	2	4	0	0
Space infection (without anastomotic and/or digestive system fistula)	238	9	5	3	1
RIs					
Sepsis (unknown cause)	24	1	0	0	0
Respiratory infection	78	1	3	0	1
Urinary tract infections	60	1	0	0	0
Catheter-related infections	44	0	6	0	0
Drain infection	20	0	1	0	0
Antibiotic-associated colitis (MRSA enteritis)	2	0	1	0	0
No infection	89	2	1	2	0

SSIs surgical site infections, *RIs* remote infections, *MRSA* methicillin-resistant *Staphylococcus aureus*, *ESBL* extended-spectrum β-lactamase-producing *Enterobacteriaceae*, *IPM-RP* imipenem-resistant *Pseudomonas aeruginosa*, *MDR-GN* multidrug-resistant Gram-negative bacteria

[a]The number of surgical cases from which any bacteria were isolated after digestive surgeries

patients with RIs. In patients with RTIs, MRSA were the most predominant AMR bacteria ($n=3$, 3.8%) followed by ESBL-producing *Enterobacteriaceae* ($n=1$, 1.3%), and IMP-RP ($n=1$, 1.3%). In patients with UTIs, only ESBL-producing *Enterobacteriaceae* ($n=1$, 1.7%) were isolated. Among patients with catheter-related infections, only MRSA were found ($n=6$, 13.6%). Patients with bacteremia solely demonstrated ESBL-producing *Enterobacteriaceae* ($n=1$, 4.2%). In those with drain-related and organ infections, only MRSA were isolated ($n=1$, 5.0%).

Colonization by AMR bacteria after digestive tract surgery

A total of 89 patients (1.2% of all surgery cases) were diagnosed with colonization with bacteria without any evidence of infection. Among them, MRSA, ESBL-producing *Enterobacteriaceae,* and MDR-GN were isolated in 1.1% ($n=1$), 2.2% ($n=2$), and 2.2% ($n=2$) of cases, respectively.

Detection of AMR bacteria after digestive tract surgery and the prognosis

The patient prognoses after digestive tract surgery are shown in Table 3. Among all patients with isolated bacteria ($n=905$), 556 (61.4%), 190 (21.0%), 67 (7.4%), 37 (4.1%), 25 (2.8%), and 27 (3.0%) were found to have a prognosis score of 0, 1, 2, 3, 4, and 5, respectively. In the entire cohort ($n=7565$), the mortality of the patients with isolated AMR bacteria was less than 0.1% ($n=5$). Among all patients with isolated bacteria ($n=905$), the mortality in those with isolated AMR bacteria was 0.6%. Patients with higher prognosis scores (3–5) showed a significantly higher frequency of the detection of AMR bacteria than those with prognosis scores of 0–2 (18.0% vs. 6.2%, $p<0.001$). In patients with prognosis scores of 5 (7.4%, $n=2$), 4 (20.0%, $n=5$), and 3 (5.4%, $n=2$), the most frequently isolated bacteria were ESBL-producing *Enterobacteriaceae* and MRSA, MRSA alone, and ESBL-producing *Enterobacteriaceae* alone, respectively.

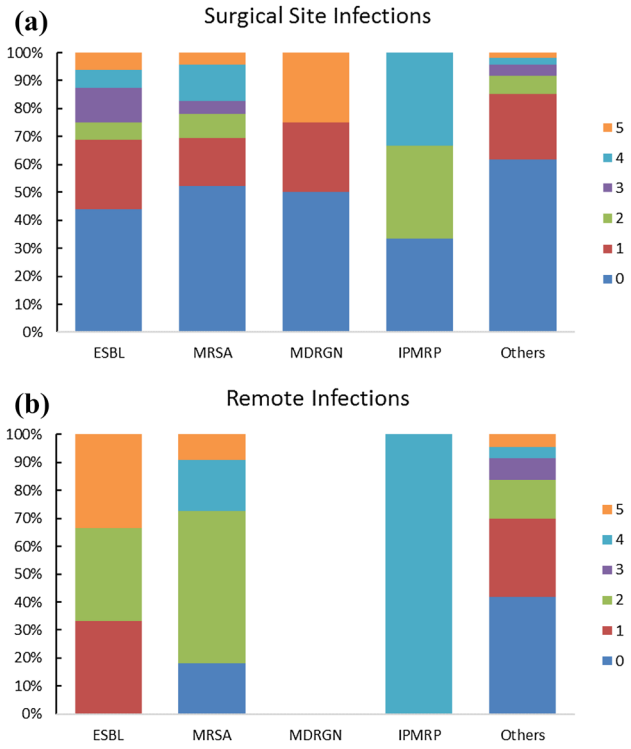

Fig. 1 Correlations between isolated AMR bacteria and the prognosis. The relationships between isolated AMR pathogens and the prognosis after surgery in SSI patients (**a**) and RI patients (**b**)

Table 3 AMR bacteria detected after digestive surgeries and the patient prognosis

	Cases (n)						
	Total [a]	ESBL	MRSA	VRE	MDRP	MDR-GN	IPM-RP
Cases (total)	905[a]	21	35	0	0	6	4
Prognosis[b]							
0	556	9	15	0	0	4	1
1	190	5	4	0	0	1	0
2	67	2	8	0	0	0	1
3	37	2	1	0	0	0	0
4	25	1	5	0	0	0	2
5	27	2	2	0	0	1	0

MRSA methicillin-resistant *Staphylococcus aureus*, *ESBL* extended-spectrum β-lactamase-producing *Enterobacteriaceae*, *IPM-RP* imipenem-resistant *Pseudomonas aeruginosa*, *VRE* vancomycin-resistant *Enterococci*, *MDR-GN* multidrug-resistant Gram-negative bacteria, *MDRP* multidrug-resistant *P. aeruginosa*

[a]The number of surgical cases from which any bacteria were isolated after digestive surgeries

[b]Patient prognoses after digestive tract surgery

Isolated AMR bacteria and the prognosis

Figure 1 shows the relationships between the isolated AMR bacteria and the post-operative patient prognosis in patients with SSIs (Fig. 1a) and RIs (Fig. 1b). Most patients with SSIs (90.1%) had prognosis scores of < 3. The distribution of the prognosis scores (0–5) was significantly different ($p = 0.013$) among the infecting AMR pathogen groups. Patients infected with ESBL-producing *Enterobacteriaceae*, MRSA, MDR-GN, IMP-RP, and other bacteria showed varying mortalities (6.3%, $n = 1$; 4.3%, $n = 1$; 25.0%, $n = 1$; 0%, $n = 0$; 1.9%, $n = 8$, respectively). However, the number of patients classified as having a score of 5 was too small to compare these mortalities among the groups. In patients with RIs, the severity scores (0–5) among patients infected with ESBL-producing *Enterobacteriaceae*, MRSA, and other bacteria were significantly different ($p = 0.004$). Most patients (81.9%) had severity scores of < 3. Those infected with ESBL-producing *Enterobacteriaceae*, MRSA, IMP-RP, and other bacteria showed varying mortalities, with ESBL-producing *Enterobacteriaceae* associated with the highest mortality (33.3%, $n = 1$; 9.1%, $n = 1$; 0%, $n = 0$; 4.7%, $n = 6$, respectively). However, the number of patients classified as having a score of 5 was too small to compare these mortalities among the groups.

Detection of AMR bacteria according to surgical sites

The frequency of the identification of AMR bacteria for each surgical site is shown in Fig. 2. The frequency of isolating AMR bacteria after digestive tract surgery varied according to the site. ESBL-producing *Enterobacteriaceae* and MRSA were the most commonly isolated bacteria in surgeries of the esophagus (5.3% and 7.0%, respectively), whereas MDR-GN were most frequently isolated in patients who had undergone surgeries of the pancreas/liver (1.3%), and IMP-RP were the most frequently infecting bacteria in patients who underwent surgeries of the gallbladder/bile duct (1.7%). The details of the surgical procedures and the isolated AMR bacteria are summarized in Tables 4 (open surgery) and 5 (laparoscopic surgery). In patients who underwent open surgeries, the rates of post-operative infections with AMR bacteria were significantly lower in the endoscopic surgery group (12 of 3,321 cases) than in the open surgery group (54 cases in 4244 cases) ($p < 0.001$) (Table 5).

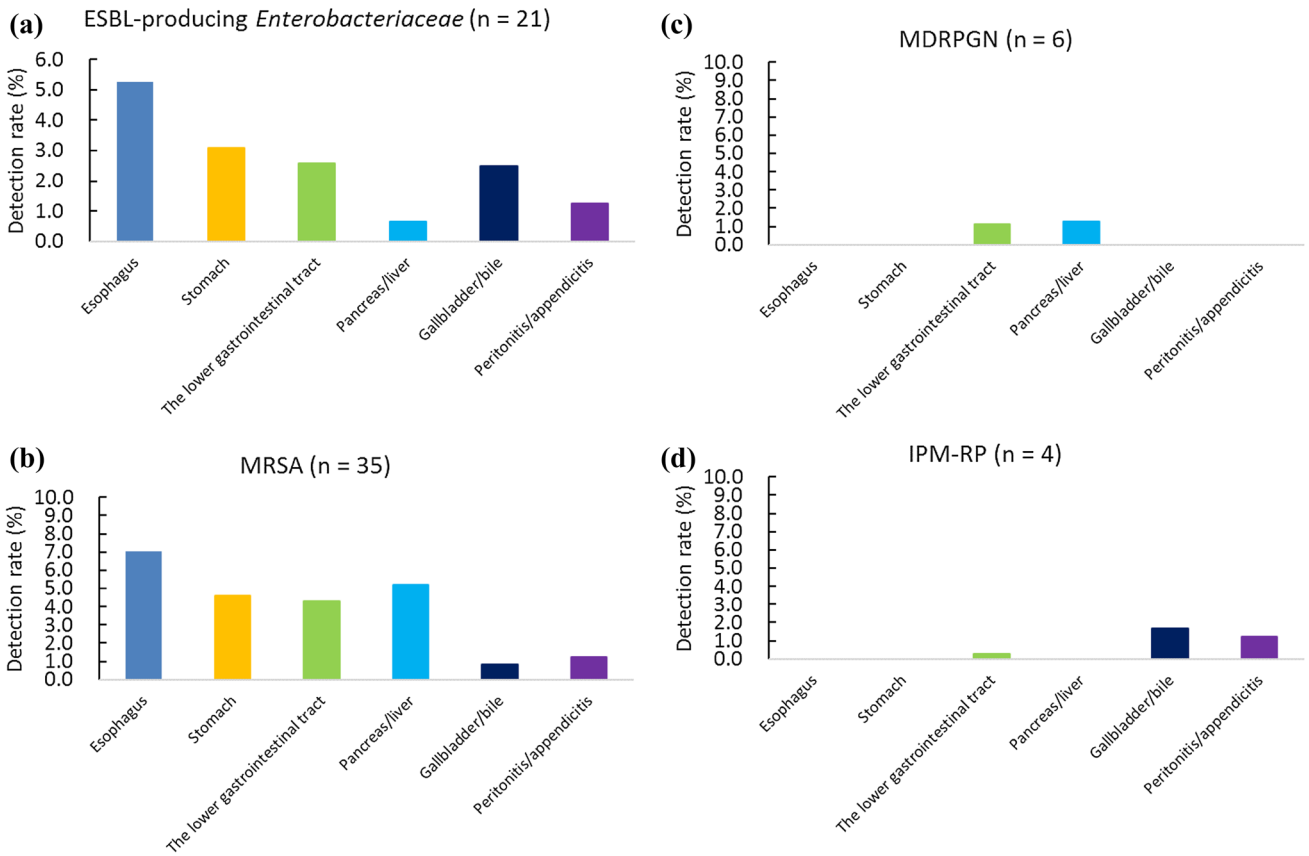

Fig. 2 AMR bacteria that were detected and the portions of the digestive tract that underwent surgery. The detection frequency of AMR bacteria (**a**: ESBL-producing Enterobacteriaceae, **b**: MRSA, **c**: MDR-GN, **d**: IPM-RP) for each operated portion is shown

Table 4 AMR bacteria detected after digestive surgeries for each open surgery type

Surgical procedure[a]	Cases (*n*)				
	Total[a]	ESBL	MRSA	MDR-GN	IPM-RP
Cases (total)	723[b]	16	31	4	3
Esophageal malignant tumor surgery (combined digestive tract reconstructive surgery)	47	2	2	0	0
Secondary reconstruction after esophagectomy	4	1	1	0	0
Reconstruction of the esophagus	2	0	1	0	0
Stomach incision	2	0	1	0	0
Stomach local excision	3	1	0	0	0
Gastrectomy	27	1	1	0	0
Cardia side gastrectomy	4	0	1	0	0
Gastrointestinal anastomosis (including Brown anastomosis)	9	0	1	0	0
Gastrostomy additional surgery (including percutaneous endoscopic gastrostomy)	3	0	1	0	0
Hepatectomy (expansion lobectomy)	14	0	1	0	0
Hepatectomy (Lobectomy)	7	0	1	0	0
Hepatectomy (expansion lobectomy with revascularization)	2	0	0	1	0
Acute disseminated peritonitis surgery	43	1	1	0	1
Colectomy (colon half-side resection)	19	2	0	0	1
Colectomy (small-range resection)	28	1	1	0	0
Colectomy (all resection, subtotal resection or malignant tumor surgery)	29	1	5	0	0
Small bowel resection	27	0	2	0	0
Colostomy closure (with intestinal resection)	19	1	0	1	0
Colostomy closure (without intestinal resection)	10	1	1	0	0
Colostomy additional surgery	25	0	2	1	0
Common bile duct stomach (intestine) anastomosis	9	1	0	0	1
Cholecystectomy	14	1	0	0	0
Bowel obstruction surgery	15	0	1	0	0
Rectal resection–amputation (amputation)	24	1	0	0	0
Rectal resection–amputation (low anterior resection surgery)	14	0	1	0	0
Pancreatic head tumor resection (lymph node dissection)	45	1	2	1	0
Pancreatic head tumor resection (combined resection of peripheral organs)	10	0	1	0	0
Pancreatic head tumor resection (amputation)	1	0	1	0	0
Head of the pancreas tail tumor resection (lymph node dissection)	13	0	1	0	0
Head of the pancreas tail tumor resection (combined resection of peripheral organs)	6	0	1	0	0

MRSA methicillin-resistant *Staphylococcus aureus*, *ESBL* extended-spectrum β-lactamase-producing *Enterobacteriaceae*, *IPM-RP* imipenem-resistant *Pseudomonas aeruginosa*, *MDR-GN* multidrug-resistant Gram-negative bacteria

[a]Surgical procedures after which any AMR bacteria were isolated from patients

[b]The number of surgical cases from which any bacteria were isolated after digestive surgeries

Discussion

Post-operative infections are one of the most common complications following major digestive tract surgery [32–34]. Minimizing the incidence remains one of the biggest challenges for infection control committees in hospitals. There are some practice protocols, which are aimed at reducing post-operative infections, such as guidance on skin preparation and antibiotic prophylaxis. Nonetheless, post-operative infections are still common, particularly in patients with open fractures. Post-operative infections owing to multidrug-resistant bacteria have been strongly associated with increased morbidity, mortality, and treatment costs in those undergoing surgery [35, 36].

The JPICS'15 survey included data from 7565 cases of digestive tract surgery to identify the current status of post-operative infections in Japan. In summary, post-operative infections or colonization were confirmed in 12.0% of the cohort. This included 8.9%, 3.0%, and 1.2% of the patients who developed SSIs, RIs, and colonization, respectively. AMR bacterial infections or colonization occurred in 0.9% ($n=66$) of all patients ($n=7,565$), which constituted 7.5% ($n=61$) of all post-operative infections ($n=816$). Conversely, the rate of AMR bacterial colonization was less than

Table 5 AMR bacteria detected after digestive surgeries for each endoscopic surgery type

Surgical procedure [a]	Cases (*n*)				
	Total	ESBL	MRSA	MDR-GN	IPM-RP
Total	182[b]	5	4	2	1
Laparoscopic gastrectomy	29	1	1	0	0
Laparoscopic total gastrectomy	9	1	0	0	0
Laparoscopic small bowel resection	5	0	1	0	0
Laparoscopic colectomy (small-range resection,·colon half-side resection)	33	1	0	2	0
Laparoscopic colectomy (all resection,·subtotal resection)	3	1	0	0	0
Laparoscopic rectal resection–amputation (amputation)	15	0	1	0	0
Laparoscopic cholecystectomy	84	1	1	0	0
Laparoscopic biliary incision stones, hysterectomy	4	0	0	0	1

MRSA methicillin-resistant *Staphylococcus aureus*, *ESBL* extended-spectrum β-lactamase-producing *Enterobacteriaceae*, *IPM-RP* imipenem-resistant *Pseudomonas aeruginosa*, *MDR-GN* multidrug-resistant Gram-negative bacteria

[a]Surgical procedures after which any AMR bacteria were isolated from patients

[b]The number of surgical cases from which any bacteria were isolated after digestive surgeries

0.1% ($n=5$) in the entire survey cohort. VRE or MDRP were not isolated from any patients in the present survey.

Irrespective of the type of surgery, ESBL-producing *Enterobacteriaceae* and MRSA were the predominant AMR bacteria isolated from patients with post-operative infections or colonization after digestive tract surgery (Table 1). In the entire survey cohort ($n=7{,}565$), the frequencies of isolating ESBL-producing *Enterobacteriaceae*, MRSA, MDR-GN, and IMP-RP were 0.3%, 0.5%, 0.1%, and 0.1%, respectively. Among them, the respective frequencies of microbiologically and clinically proven post-operative infections during the study period were 0.3%, 0.4%, 0.1%, and 0.1%.

In a previous study, the incidence of MRSA infections after colorectal surgery was reported to be 0.9% [37]. A UK surveillance study had reported that the rate of ESBL-producing *Enterobacteriaceae* increased significantly from 11.5% in 2007 to 15.4% in 2012 [38]. In the current survey, the rates of infection with AMR bacteria were lower than in the previous reports [16, 37, 39]. The rate of post-operative infections varied according to the type of surgery, surveillance intensity, available resources for microbial detection, and hospital type, among the other factors. However, the results of this study revealed that AMR bacterial infections accounted for 7.5% of post-operative infections. These findings suggest that antibacterial coverage against AMR bacteria should be considered in all patients with either critical post-operative infections or a high risk of MDR infections.

In the present study, the proportion of cases detected with AMR bacteria after digestive tract surgery was higher among elderly patients than among younger patients (Table 1). Post-operative infections due to AMR bacteria are expected to continue to rise with the increase in the elderly population. In our survey, the patients who had colonization with bacteria in the pharynx, respiratory tract, urine, and stool before digestive tract surgery had greater than 10% incidence of post-operative infections or colonization due to AMR bacteria (Table 1). The correct use of antibiotics, strict infection prevention and control measures have been reported to reduce the rates of post-operative infection significantly, including post-operative infections caused by AMR bacteria [40]. Therefore, patients with colonization should be offered carefully chosen prophylactic measures and antibacterial coverage before any surgery is performed on the digestive tract.

In our cohort, patients with higher prognosis scores had a higher AMR bacteria detection rate than those with lower scores (Table 3). Among all patients with post-operative infections, including those with colonization ($n=905$), the mortality among those with isolated AMR bacteria was 0.6%. Compared to patients with significantly lower prognosis scores (0–2), patients with higher prognosis scores (3–5) had higher ratios of post-operative AMR bacterial infections and colonization ($p<0.001$). Therefore, in agreement with the findings of the previous studies, post-operative infections with AMR bacteria resulted in increased rates of morbidity and mortality [35, 36].

In the present survey, the frequency of isolated AMR bacteria varied according to the surgical site (Fig. 1). We speculate that these results are derived from the differences in surgical procedures by surgical type and the normal bacterial flora at individual surgical sites. The rates of post-operative infections also varied according to the type of surgery. Compared to the patients who underwent open surgery, the rates of detection of AMR bacteria were significantly lower in the group undergoing endoscopic surgery ($p<0.001$) (Tables 4, and 5). Typically, endoscopic surgery utilizes small wound

incisions, which minimize wound pain and reduce the risk of post-operative infection, including that caused by AMR bacteria.

In the present survey, we identified 674 (8.9%) SSIs and 228 (3.0%) RIs in 7,565 surgeries (with bacteria detected in 74.5% and 25.2% of cases, respectively). Among the cases with SSIs, 46 patients (6.8%) were infected with AMR bacteria, of which MRSA were the most prevalent bacteria, accounting for 3.4% ($n=23$) of the isolates (Table 2). The incidence of SSIs in our survey was similar to that of the previous studies in other countries [41–43]. Conversely, the incidence of RIs was lower than that of studies from other countries [44, 45]. In the present study, among patients with RIs, 15 (6.6%) were infected with AMR bacteria, of which MRSA were the most frequently found (4.8%), followed by ESBL-producing *Enterobacteriaceae* (1.3%) and IMP-RP (0.4%). These results may partially be explained by the fact that, in Japan, surgeons directly manage all aspects of post-operative patient care, including the prevention of SSIs and RIs.

Our study has several limitations inherent to its design. First, as in any retrospective study, several instances of bias were probably introduced despite using standard definitions for post-operative infection and colonization. Second, the observation period was limited to the period lasting until discharge, and the 30 day-post-operative status was not evaluated. Therefore, the observation period of the present survey was shorter than that of previous surveys. However, despite these limitations, this study possesses several strengths. It was conducted by the Japan Society for Surgical Infection and included 28 centers. To our knowledge, this is the largest multicenter study to focus on post-operative infections throughout Japan. This survey included a substantial number of surgical procedures and post-operative infections. In addition, this is the first report to examine the prevalence of AMR bacterial colonization after digestive tract surgery.

In conclusion, the JPICS'15 survey revealed that infections or colonization with AMR bacteria occurred in 0.9% of patients who underwent digestive tract surgery and accounted for 7.5% of post-operative infections. ESBL-producing *Enterobacteriaceae* and MRSA were the predominant AMR bacteria isolated from patients after digestive tract surgery; patients infected with AMR bacteria-related SSIs and RIs had a poor prognosis. The individual AMR bacteria showed variations in distributions according to the individual surgical sites and procedures.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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