Evaluation of Hospital-onset Bacteremia and Fungemia in the United States as a Potential Healthcare Quality Measure: A Cross-Sectional Study

Supplementary Material

Methods

Site Selection: This study was designed as a collaborative study across 6 academic members of the Centers for Disease Control and Prevention's Prevention Epicenters program. Hospitals affiliated with those 6 sites were eligible; participation of up to one academic, one children's, and one community hospital from each site was requested. The final determination of hospitals was made by the site PI.

Sample size calculation:

We calculated the sample size of total hospital-onset bacteremia and fungemia (HOB) events needed to detect a 0.10 point difference in the probability that an HOB event is preventable when a binary predictor X=1 versus when X=0, when the proportion of events where X=1 is as low as 0.15 (say, for example, X is presence of invasive device). We assumed the proportion of variance of X explained by other predictors (R^2) equaled 0.25. We specified a two-sided test, power = 0.80, and alpha (probability of Type I error) = 0.05. With these specifications, the sample size required is 1998.

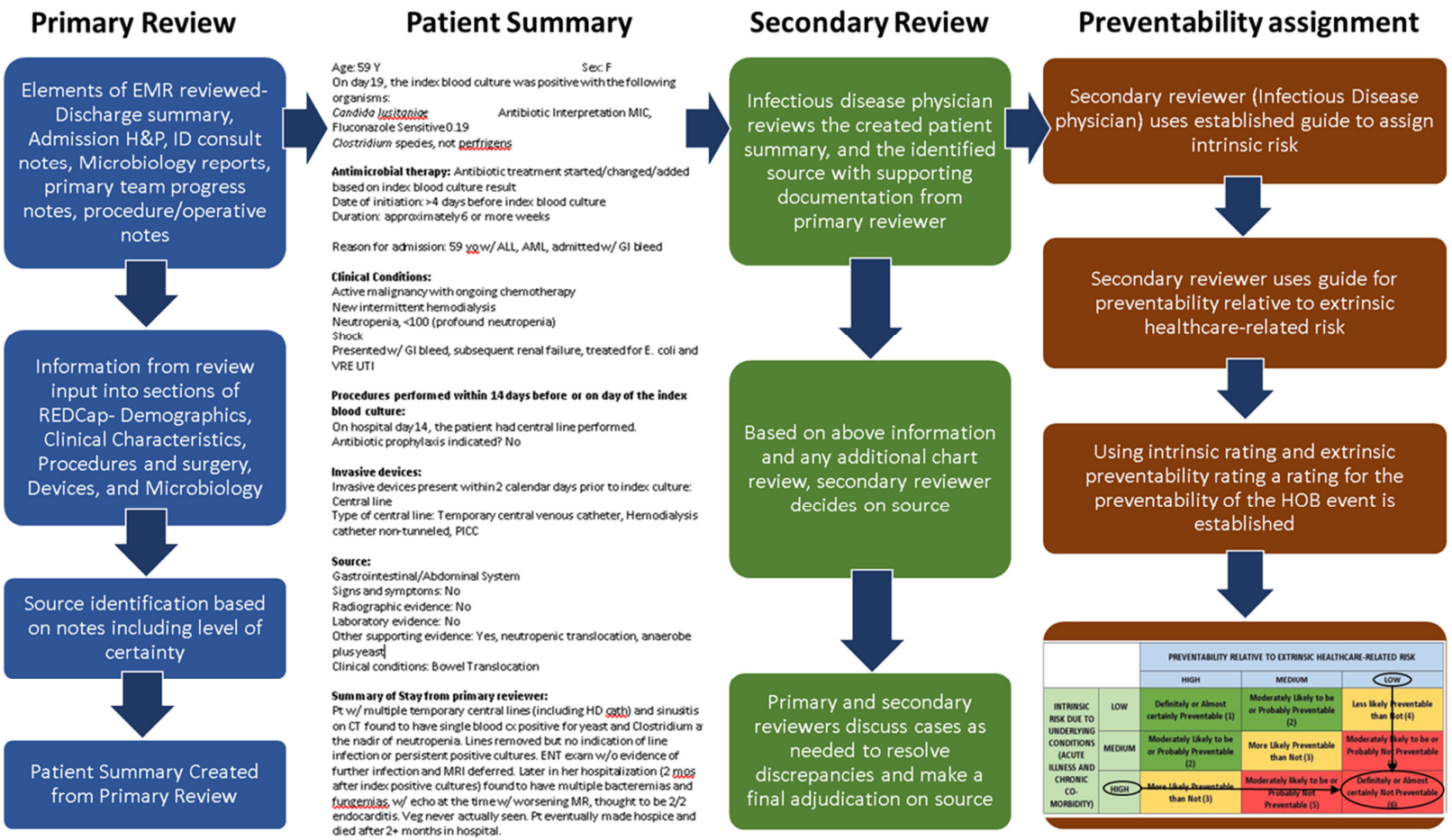
Justification for targets for specified commensal to non-commensal and pediatric to adult ratios: Prior studies show that among all positive blood cultures, up to 30-50% may be attributed to blood culture contamination with common skin commensals(1,2). However, commensal organisms may also cause true bloodstream infection -- among central line associated bloodstream infections (CLABSI) reported to National Healthcare Safety Network, approximately 20% are attributed to commensal organisms.(3) Therefore, to include adequate numbers of commensal HOB cases to evaluate their sources and preventability but avoid oversampling of HOB with contaminated blood cultures, we included HOB cases

with commensals at a lower proportion than we would obtain from simple random sampling. Similarly, a prior study shows that pediatric cases constitute approximately 15% of cases among all bloodstream infections.(1) Therefore, to ensure adequate numbers of pediatric cases from the included study hospitals, we aimed for a pediatric to adult ratio of 1:5.

Standardization of Chart Review and Preventability Assessments:

Prior to embarking on this large multicenter study of HOB sources and preventability, we had completed two studies preparatory to this work. The first was a pilot study of assessing HOB preventability in a small sample of 60 cases where we used a two-person adjudication process.(4) It was clear from that pilot study that further standardization of the method to rate preventability was necessary. It was also clear that two-person review for a study of a larger magnitude would be laborious. Therefore, we considerably expanded the preventability rating framework to account for a large number of sources of HOB and associated patient intrinsic risk. In a separate study(5), we developed HOB scenarios that were rated by a panel of physicians to develop a "consensus" preventability rating for each scenario. We then validated the structured preventability rating guide against the consensus ratings, and measured inter-rater reliability of two additional independent reviewers, with iterative refinement of the structured rating guide in the process. In the present study, this final structured rating guide was then used by a single secondary reviewer who determined preventability, as shown in the flowchart for HOB standardized reviews (Supplementary Figure 1).

Supplementary Figure 1: Flowchart for Hospital onset bacteremia and fungemia standardized reviews



Supplementary Figure 2: Preventability Risk Assessment matrix

		PREVENTABILITY RELATIVE TO EXTRINSIC HEALTHCARE-RELATED RISK		
		HIGH	MEDIUM	LOW
INTRINSIC RISK DUE TO UNDERLYING CONDITIONS (ACUTE ILLNESS AND CHRONIC CO-MORBIDITY)	LOW	Definitely or Almost certainly Preventable (1)	Moderately Likely to be or Probably Preventable (2)	Less likely Preventable than Not (4)
	MEDIUM	Moderately Likely to be or Probably Preventable (2)	More Likely Preventable than Not (3)	Moderately likely to be or Probably Not Preventable (5)
	HIGH	More Likely Preventable than Not (3)	Moderately likely to be or Probably Not Preventable (5)	Definitely or Almost certainly Not Preventable (6)

Clinical characteristics: Definitions and Instructions for chart review

Clinical Characteristics		
Data Field	**Data Entry menu (as in Redcap)**	**Definitions and Instructions**
Characteristics of current illness (Admission Diagnoses)	***Includes significant illnesses and conditions present prior to onset of bacteremia in this encounter. Can select multiple conditions if applicable. Review admission H&P and progress notes from time of admission to the day of the index positive blood culture.***	
Immunosuppressive therapy	Select no or all that apply	
	Active malignancy with ongoing chemotherapy	Receiving chemotherapy drugs or cycle in **during current encounter or in the last 30 days**. *Review progress notes, if necessary review medication administration records,* ***See appendix IX for list of chemotherapeutic drugs.***
	Receiving immunosuppressive or immunomodulator therapy	Receiving corticosteroid or immunomodulatory drugs for acute severe autoimmune disease like ulcerative colitis, rheumatoid arthritis, or other Connective Tissue Disease **during current encounter or in the last 30 days.** ***See appendix IX*** *for list of chemotherapeutic drugs.*
	Radiation therapy	Radiation therapy for active malignancy, **during current encounter or within the last 30 days**
Long-term immunosuppression	Select yes or no	Patient on long-term/chronic immunosuppressive therapy (> 30 days) regardless of whether receiving it during current encounter; include monoclonal antibody treatment (e.g., rituximab, infliximab etc. **if received within the last 6 months**)
Burns and other skin conditions	Select no, burn, or Desquamating skin	Select "burn" for a patient with a burn requiring admission to a burn unit. Desquamation also called skin peeling, is the shedding of the outermost membrane or layer of a tissue, such as the skin. Some conditions which produce desquamation of the skin are Toxic Shock

		Syndrome, Toxic Epidermal Necrolysis (TEN), severe Stevens Johnson syndrome.
Cardiorespiratory arrest and received CPR before index blood culture	Select Yes or No	If the patient had an episode(s) of Cardiorespiratory arrest leading to the current admission or during this admission prior to the index blood culture and received CPR. Cardiopulmonary resuscitation (CPR) is an emergency procedure that combines chest compressions often with artificial ventilation in an effort to manually preserve intact brain function until further measures are taken to restore spontaneous blood circulation and breathing in a person who is in cardiac arrest
Dialysis	Select no or one of the choices to the left	• New intermittent hemodialysis for acute kidney injury during current encounter prior to index blood culture • New continuous renal replacement therapy for acute kidney injury during current encounter prior to index blood culture • Chronic hemodialysis via AV graft or fistula • Chronic hemodialysis via hemodialysis catheter • Chronic peritoneal dialysis
Decubitus ulcer	Select Yes or No	Acute, developed during current stay and before index blood culture Chronic and present at the time of admission
Drug use disorder	Select yes or no	
	Current vs. past use	Current drug use Past h/o of drug use disorder (DUD), no ongoing drug use Past h/o of DUD, unclear if current use
	Marijuana, cannabinoid (other than smoking) DUD/Abuse	IDU/Skin popping/Non IDU/Unknown
	Opioid, DEA schedule (e.g., Heroin) DUD/Abuse	IDU/Skin popping/Non IDU/Unknown
	Cocaine or methamphetamine DUD/Abuse	IDU/Skin popping/Non IDU/Unknown
	Other (specify) DUD/Abuse	IDU/Skin popping/Non IDU/Unknown
	Unknown Substance	IDU/Skin popping/Non IDU/Unknown
Neutropenia	Select Yes or No	An abnormal decrease in absolute Neutrophil count, <1000 cell/microliter, on at least 2 separate days within **1 week (+/-7 days) of the index positive blood culture**, but not as a result of the index bacteremia/fungemia.
		If yes, select nadir WBC count • < 100 (profound neutropenia) • 100 to < 500 (severe neutropenia) • 500 to < 1000 (neutropenia)

Organ transplant	Select no or one of the below choices	
	Solid Organ Transplant	Organ transplantation is a procedure in which an organ is removed from one body and placed in the body of a recipient, to replace a damaged or missing organ (e.g., liver, kidney, heart, lung, pancreas, small bowel). Transplants performed between two subjects of the same species are called allografts. Allografts can either be from a living or cadaveric source.
	Stem or Bone marrow transplant	May be indicated as 'bone marrow transplant' (BMT), 'Hematopoietic stem cell transplantation' (HSCT), or 'peripheral blood stem cell transplantation' (PBSCT), or cord blood stem cell transplant
Transplant Time period	Select one of the following: 1. During the current admission (and prior to index blood culture) 2. In the last 30 days, but not during the current admission 3. Any time in the past	If the patient received a solid organ transplant prior to the index blood culture, indicate time-period.
Shock	Select Yes or No	*Review progress notes for diagnosis of shock;* select yes if patient had shock **within 30 days prior to index blood culture**
Total Parenteral Nutrition (TPN)	Select Yes or No	TPN is feeding a person intravenously, bypassing the usual process of eating and digestion using nutritional formulae that contain nutrients such as glucose, amino acids, lipids and added vitamins and dietary minerals. Select TPN if patient received TPN **within 1 week prior to the index blood** culture during the encounter.
Trauma	Select none, blunt, penetrating or both	Select according to site of trauma present as mentioned in admission notes; select if patient presented with trauma **within 30 days prior to index blood culture**
Sickle cell disease	Select Yes or No	Indicate if the patient has a diagnosis of sickle cell disease. DO NOT indicate if patient is specified as having 'sickle cell trait'; sickle cell trait generally does not cause disease.
If yes, was patient in sickle cell crisis?	Select Yes or No	Sickle cell crisis a broad term describing several different acute conditions occurring as part of sickle cell disease, such as aplastic crisis, hemolytic crisis, and vaso-occlusive crisis. select yes if patient presented with sickle cell crisis **within 30 days prior to index blood culture**
Smoking/ Tobacco use	Select Yes or No	Includes a smoker of cigarettes, cigars or the consumption of inhaled tobacco through other devices, such as a hookah, but does not include smoking crack or other illicit drugs. Clarification: Do not include patients who are being treated with or noted to have used "medical marijuana". Please check if smoking is current or if the

		timing of the use is unknown. Do not check if clearly stated that the patient had a "history" of smoking or is indicated as a "former" smoker. HOWEVER, if the person recently quit smoking (i.e. quit smoking within the past 12 months) please select yes. *Review admission H&P in social history section*
Other clinical conditions which may be relevant		Free text if any clinical condition that may be relevant to the HOB event

Supplementary Material: Results

Supplementary Table 1: Microbiologic characteristics of hospital-onset bacteremia and fungemia (HOB) cases

	Overall n (%) (N=2109)	**Adult n (%) (N=1754)**	**Pediatrics n (%) (N=355)**	**Academic n (%) (N=1768)**	**Community n (%) (N=341)**
Polymicrobial (among all cases n=2109)**	191 (9.0)	159 (9.1)	32 (9.0)	168 (9.5)	23 (6.7)
Median number of organisms (interquartile range (IQR))	1 (1-1)	1 (1-1)	1 (1-1)	1 (1-1)	1 (1-1)
Non-commensal HOB cases (n=1789)		**(n=1504)**	**(n=285)**	**(n = 1525)**	**(n=264)**
Proportion of patient with additional positive blood cultures*	459 (25.7)	376 (25.0)	83 (29.1)	367 (24.1)	92 (34.8)
Median number of positive blood cultures (IQR)*	0 (1-1)	0 (0-0.5)	0 (0-1)	0 (0-0)	0 (0-1)
Proportion of patients with matching blood cultures*	264 (14.8)	214 (14.2)	50 (17.5)	200 (13.1)	64 (24.2)
Proportion of patients with matching blood cultures within 14 days before*	127 (7.1)	111 (7.4)	16 (5.6)	76 (5.0)	51 (19.3)
Proportion of patients with matching blood cultures within 14 days after*	141 (7.9)	105 (7.0)	36 (12.6)	128 (8.4)	13 (4.9)
Proportion of patients with a positive non-commensal blood culture within 14 days before*	184 (10.3)	166 (11.0)	18 (6.3)	111 (7.3)	73 (27.7)
Proportion of patients with a positive blood culture in the first 3 days of their hospital stay***	127/1123 (11.3)	114/994 (11.5)	13/129 (10.1)	61/919 (6.6)	66/204 (32.4)
Median duration between closest matching blood culture before index blood culture (IQR)	7 (4-11)	6 (4-10)	9 (5-12)	7 (4-11)	5 (3-8)
Median number of clinical and blood cultures regardless of results other than index blood culture	0 (0-2)	0 (0-2)	0 (0-2)	0 (0-2)	1 (0-2)
Proportion of patients with positive clinical cultures or blood cultures before index blood culture	503 (28.1)	424 (28.2)	79 (27.7)	396 (26.0)	107 (40.5)
Median number of positive clinical cultures or blood cultures before (IQR)	0 (0-1)	0 (0-1)	0 (0-1)	0 (0-1)	0 (0-1)
Median number of positive clinical cultures (IQR)*	0 (0-1)	0 (0-1)	0 (0-1)	0 (0-1)	0 (0-1)
Proportion of patients with matching clinical non-blood culture*	558 (31.2)	426 (31.2)	132 (46.3)	468 (30.7)	90 (34.1)
Proportion of patients with matching clinical non-blood culture within 14 days before*	181 (10.1)	154 (10.2)	27 (9.5)	146 (9.6)	35 (13.3)
Proportion of patients with matching clinical non-blood culture on or within 14 days after*	462 (25.8)	339 (22.5)	123 (43.2)	392 (25.7)	70 (26.5)
Non-commensals considered contaminants	60 (3.4)	52 (3.5)	8 (2.8)	58 (3.8)	2 (0.8)
Commensal HOB cases (n=320)		**(n= 250)**	**(n=70)**	**(n=243)**	**(n=77)**
Commensals considered true blood stream infections	94 (29.4)	72 (28.8)	22 (31.4)	83 (34.2)	11 (14.3)
Commensals considered contaminants	182 (56.9)	143 (57.2)	39 (55.7)	129 (53.1)	53 (56.9)
Commensals considered true blood stream infections and contaminants	34 (10.6)	28 (11.2)	6 (8.6)	23 (9.5)	11 (10.6)
Commensals with no source	10 (3.1)	7 (2.8)	3 (4.3)	8 (3.3)	2 (3.1)

*Before or after 14 days from index blood culture unless otherwise noted, index blood culture not included unless otherwise noted

**Polymicrobial is defined as two or more organisms that are different in the same blood culture set

***Only includes non-commensal index blood cultures within the first 14 days of admission

Supplementary Table 2: Distribution of sources and sites of infection among hospital-onset bacteremia and fungemia events associated with non-commensal organisms (N=1789)

Source	Overall n (%) (N=1789)		Adult n (%) (N=1504)		Pediatric n (%) (N=285)		Academic n (%) (N=1525)		Community n (%) (N=264)	
Gastrointestinal/abdominal	**622**	**(34.8)**	**547**	**(36.4)**	**75**	**(26.3)**	**553**	**(36.3)**	**69**	**(26.1)**
Gastrointestinal/abdominal (non-neutropenic/non-hepatobiliary)[a]	397	(63.8)	354	(64.7)	43	(57.3)	343	(62.0)	54	(78.3)
Neutropenic translocation	194	(31.2)	161	(29.4)	33	(44)	191	(34.5)	3	(4.3)
Hepatobiliary source	90	(14.5)	88	(16.1)	2	(2.7)	74	(13.4)	16	(23.2)
Endovascular	**563**	**(31.5)**	**478**	**(31.8)**	**85**	**(29.8)**	**485**	**(31.8)**	**78**	**(29.5)**
Intravascular catheter[b]	488	(86.7)	408	(85.4)	80	(94.1)	424	(87.4)	64	(82.1)
Total Central Line	435	(77.3)	358	(74.9)	77	(90.6)	375	(77.3)	60	(76.9)
Central line- tunneled and port	157	(27.9)	131	(27.4)	26	(30.6)	126	(26)	31	(39.7)
Peripherally inserted central catheter	155	(27.5)	132	(27.6)	23	(27.1)	139	(28.7)	16	(20.5)
Central line-temporary	132	(23.4)	115	(24.1)	17	(20)	119	(24.5)	13	(16.7)
Peripheral Intravascular[c]	76	(13.5)	73	(15.3)	3	(3.5)	72	(14.8)	4	(5.1)
Endovascular-Other	187	(10.5)	167	(11.1)	20	(7.0)	153	(10.0)	34	(12.9)
Respiratory tract	**208**	**(11.6)**	**169**	**(11.2)**	**39**	**(13.7)**	**187**	**(12.3)**	**21**	**(8)**
Pneumonia	111	(53.4)	98	(58)	13	(33.3)	96	(51.3)	15	(71.4)
Ventilator-associated pneumonia	64	(30.8)	51	(30.2)	13	(33.3)	60	(32.1)	4	(19)
Respiratory tract-Other	47	(22.6)	33	(19.5)	14	(35.9)	42	(22.5)	5	(23.8)
Urinary	**176**	**(9.8)**	**166**	**(11)**	**10**	**(3.5)**	**141**	**(9.2)**	**35**	**(13.3)**
Indwelling urinary catheter-associated	64	(36.4)	60	(36.1)	4	(40)	55	(39)	9	(25.7)
Cystitis/lower tract	56	(31.8)	54	(32.5)	2	(20)	47	(33.3)	9	(25.7)
Pyelonephritis/Upper tract	38	(21.6)	35	(21.1)	3	(30)	29	(20.6)	9	(25.7)
Urinary- Other	43	(24.4)	42	(25.3)	1	(10)	31	(22)	12	(34.3)
Skin and soft tissue infection	**157**	**(8.8)**	**142**	**(9.4)**	**15**	**(5.3)**	**123**	**(8.1)**	**34**	**(12.9)**
Cellulitis	59	(37.6)	51	(35.9)	8	(53.3)	45	(36.6)	14	(41.2)
Cutaneous abscess	33	(21)	29	(20.4)	4	(26.7)	20	(16.3)	13	(38.2)
Skin and soft tissue -Other	98	(62.4)	91	(64.1)	7	(46.7)	85	(69.1)	13	(38.2)
Surgical site infection	**102**	**(5.7)**	**94**	**(6.3)**	**8**	**(2.8)**	**90**	**(6.0)**	**12**	**(4.5)**
Bone and joint	**84**	**(4.7)**	**76**	**(5.1)**	**8**	**(2.8)**	**64**	**(4.2)**	**20**	**(7.6)**
Osteomyelitis	65	(77.4)	57	(75)	8	(100)	53	(82.8)	12	(60)
Septic Arthritis	26	(31)	22	(28.9)	4	(50)	18	(28.1)	8	(40)
Bone and Joint-Other	21	(25)	20	(26.3)	1	(12.5)	19	(29.7)	2	(10)
Central nervous system	**20**	**(1.1)**	**16**	**(1.1)**	**4**	**(1.4)**	**19**	**(1.2)**	**1**	**(0.4)**
Reproductive	**19**	**(1.1)**	**17**	**(1.1)**	**2**	**(0.7)**	**14**	**(0.9)**	**5**	**(1.9)**
Other source	**58**	**(3.2)**	**46**	**(3.1)**	**12**	**(4.2)**	**52**	**(3.4)**	**6**	**(2.3)**

Possible contaminant	60	(3.4)	52	(3.5)	8	(2.8)	58	(3.8)	2	(0.8)
No source identified	312	(17.4)	211	(14)	101	(35.4)	277	(18.2)	35	(13.3)
Agreement between primary and secondary reviewer										
Agree	1431	(80)	1198	(79.7)	233	(81.8)	1198	(78.6)	233	(88.3)
Partially agree	268	(15)	230	(15.3)	38	(13.3)	242	(15.9)	26	(9.8)

[a] Appendicitis, gastroenteritis, infected necrotizing pancreatitis, intra-abdominal abscess, ischemic bowel, pancreatitis, peritonitis, bowel translocation without neutropenia, other gastrointestinal/abdominal source

[b] Peripherally inserted central catheter, Central Venous Catheter (temporary or tunneled), peripheral intravascular catheter, multiple intravascular access, implanted port, arterial catheter, extra-corporeal membrane oxygenation cannula, midline, umbilical catheter, intra-aortic balloon pump

[c] Peripheral intravascular catheter and midline

Main sources are shown as column percentages of the column total; source subcategories are shown as column percentages among the total for that source, where applicable. Attribution of sources and subcategories of each source were not mutually exclusive, therefore column percent totals may exceed 100%.

Supplementary Table 3: Distribution of hospital-onset bacteremia and fungemia (HOB) sources by micro-organism among non-commensal HOB cases, N=1789

Organism	Total n	Gastrointestinal/ abdominal			Endovascular			Respiratory Tract			Urinary			Skin and Soft Tissue Infection		
		n, row %, col%			n, row %, col%			n, row %, col%			n, row %, col%			n, row %, col%		
Staphylococcus aureus	***407***	17	4%	3%	196	48%	38%	65	16%	37%	7	2%	4%	83	20%	63%
Escherichia coli	***269***	156	58%	29%	28	10%	5%	21	8%	12%	58	22%	35%	9	3%	7%
***Candida* species**	***179***	75	42%	14%	81	45%	16%	7	4%	4%	15	8%	9%	6	3%	5%
Klebsiella pneumoniae	***155***	81	52%	15%	23	15%	4%	16	10%	9%	31	20%	19%	4	3%	3%
Enterococcus faecalis	***156***	58	37%	11%	78	50%	15%	8	5%	4%	18	12%	11%	4	3%	3%
Enterococcus faecium	***123***	86	70%	16%	37	30%	7%	3	2%	2%	5	4%	3%	2	2%	2%
Pseudomonas aeruginosa	***109***	27	25%	5%	29	27%	6%	34	31%	19%	18	17%	11%	13	12%	10%
Enterobacter cloacae	***83***	34	41%	6%	24	29%	5%	11	13%	6%	10	12%	6%	3	4%	2%
Serratia marcescens	***52***	10	19%	2%	20	38%	4%	13	25%	7%	3	6%	2%	7	13%	5%

Organism	Total n	Bone and Joint			Central Nervous System			Reproductive			Other Source			No Source		
		n, row %, col %			n, row %, col%			n, row %, col%			n, row %, col%			n, row %, col%		
Staphylococcus aureus	***407***	63	15%	77%	14	3%	74%	2	0%	15%	11	3%	28%	66	16%	27%
Escherichia coli	***269***	4	1%	5%	2	1%	11%	6	2%	46%	4	1%	10%	31	12%	12%
***Candida* species**	***179***	1	1%	1%	0	0%	0%	0	0%	0%	8	4%	21%	40	22%	16%
Klebsiella pneumoniae	***155***	2	1%	2%	1	1%	5%	0	0%	0%	3	2%	8%	26	17%	10%
Enterococcus faecalis	***156***	3	2%	4%	0	0%	0%	2	1%	15%	1	1%	3%	25	16%	10%
Enterococcus faecium	***123***	3	2%	4%	0	0%	0%	1	1%	8%	2	2%	5%	11	9%	4%
Pseudomonas aeruginosa	***109***	4	4%	5%	2	2%	11%	0	0%	0%	1	1%	3%	14	13%	6%
Enterobacter cloacae	***83***	0	0%	0%	0	0%	0%	1	1%	8%	4	5%	10%	24	29%	10%
Serratia marcescens	***52***	2	4%	2%	0	0%	0%	1	2%	8%	5	10%	13%	12	23%	5%

Supplementary Table 4: Summary of themes and representative reasons provided to support ratings of extrinsic preventability

Extrinsic Preventability Rating	Theme	Representative Comments
High	Vascular catheter-related infection considered preventable with optimal infection prevention practice	• "This PIV infection should be preventable- IV could have been removed at first notice of concern prior to developing a fulminant infection" • "Tunneled catheter with MSSA bacteremia soon(2 days) after line insertion"
	Surgical site infection considered preventable with optimal infection prevention practice such as infection after elective, clean surgery (e.g., cardiac, spine surgery, joint replacement)	• "The patient had a surgical site infection for a microorganism that it's usually not a skin colonizer. The surgery was considered clean, and it usually does not require prolonged ICU stay. I think that this could have been preventable, despite having the postoperative hematoma."
	Other complication from surgery or procedure	• "The infection was clearly secondary to peritonitis due to Gtube perforation into peritoneum, which was a procedural complication and preventable. It is also possible earlier identification of perforation may also have prevented the severe complications."
	Urinary tract infection due to indwelling urinary catheter	• "Given already identified UTI 2 days prior, ongoing foley and bacteremia seem fully preventable" • "Infection does appear most likely related to trauma from urinary catheter"
	Pressure ulceration with development or progression during hospital stay	• "Decubitus ulcer worsening during hospitalization" • "A pressure ulcer getting infected to point of bacteremia seems preventable with enhanced wound care and earlier treatment"
	Delay in appropriate care (e.g., recognition or timely diagnosis or management)	• "Delay in recognition and treatment of endovascular infection leading to prolonged bacteremia and likely septic arthritis" • "Delay in recognition of infection (infectious workup not started until hospital day 3) that lead to persistent bacteremia"
	Recurrence or relapse due to inadequate treatment or poor source control	• "ID consult 3 days prior to the bacteremia were already recommending new debridement of wounds (poor response to antibiotics and poor source control)" • "Delay in performing source control"
	Unnecessary devices	• "It was not clear that a PIV was necessary at the time of the infection as the patient was otherwise ready for discharge, possible removal of PIV could have prevented opportunity for infection."

	Contaminated blood culture	• "Contaminated blood culture in patient without skin conditions"
	Unnecessary blood culturing	• "Blood cultures were taken in an hemodynamically stable patient, without fever, at time of new intravenous line placement (not sure why blood cultures were taken, no clear indication)."
	Other preventable complications of medical care	• "Infection due to infected hematoma at an injection site, which seems preventable, and earlier identification of infected hematoma may have prevented bacteremia."
Medium	Vascular catheter-related infection that may not necessarily be preventable	• "Suspected line infection, which is most likely from hematogenous (GI) source, however patient also on TPN and there might be some risk due to line management."
	Surgical site infection or complication not clearly preventable e.g., abdominal or contaminated surgical site	• "Complication after multiple complicated abdominal surgeries with enteroanastamotic fistula" • "anastomotic leak" • "Perforation after complex elective surgery for cancer including diaphragm resection" • "Open chest with mediastinal bleeding. Potentially optimal wound care/occlusive dressing to avoid respiratory secretions getting into medistinum could have prevented."
	Possible delay in appropriate care	• "Patient had a known fluid collection on empiric antibiotics, however developed significant infection leading to bacteremia. Possible earlier drainage of the fluid collection could have prevented bacteremia."
	Unnecessary blood culturing	• "Likely translocation in dying patient but cultures drawn unnecessarily before change to clinical goals of care"
	Uncertainty of source	• "Initial bacteremia likely GI source from colitis but seeded line so earlier removal of line may have shortened duration of bacteremia"
	Infection related to a necessary device	• "likely source is CAUTI, which is possibly preventable, however, in this case the urine catheter was necessary"
	Urinary retention	• "Known urinary retention and recurrent UTI. Though more frequent straight cath may have prevented the UTI, the patient had other challenges precluding this plan, so likely not preventable when consideration of those factors."
	Blood culture contamination that may not necessarily be preventable	• "Contaminated blood culture during rapid response event"
	Ventilator associated pneumonia	• "VAP, prolonged ventilation but unable to liberate" "no alternative to prolonged mechanical ventilation given goals of care" "The patient was needing ventilatory support and measures to avoid aspiration were in place. "
	Aspiration with possible opportunity for prevention	• "Most likely aspirated due to seizure. Needed a second stent as missed anti-platelet therapy, and had extension of CVA with bleed when thrombosed. This may have led to seizure and then aspiration."

		"Recurrent episodes of aspiration requiring re-evaluation of diet recommendations"
Low	Nonmodifiable gastrointestinal tract translocation	• "Colitis of unclear etiology in this immunocompromised host" "Neutropenic colitis" "Complication of liver failure in already immunocompromised host"
	Patient behavior	• "Advanced metastatic Staph aureus infection with endovascular and bone/joint, soft tissue sources. Refused intervention on shoulder septic arthritis." "bacteremia due to patient self-injection into line" "I think that source could have been GI Tract-- micro-perforation after continued foreign body ingestion of things. She was already in a psych unit, receiving treatment and apparently cooperating. I don't know how this could have been prevented"
	Urinary tract in absence of indwelling catheter or retention	• "transplant pyelonephritis" "No prior GU instrumentation or foley catheter that I could find. Possibly fecal contamination in perineal region with amount of diarrhea but unclear if that was truly preventable."
	Uncertainty of source	• "Unclear source makes it difficult to identify preventable factors"
	Aspiration without opportunity for prevention	• "Patient had an aspiration due to vomiting, but he was tolerating enteral feeds and was on laxatives. So, i think that the vomiting could not have been prevented. No reported increased secretions in previous days either."
	Other nonmodifiable infectious source	• "Ongoing bacteremia from endocarditis with vegetations likely not preventable"

Supplementary Table 5: Perceived preventability of hospital-onset bacteremia and fungemia (HOB) cases by patient and microbial characteristics in categories of Preventable (rated 1-2), Uncertain (rated 3-4), and Not preventable (rated 5-6)

	Overall n=1789 n (%)	Preventable n (%)	Uncertain n (%)	Not Preventable n (%)
Demographics				
Neonates (0-27 days)	62 (3.5)	6 (9.7)	12 (19.4)	44 (71)
Infant and toddlers (28 days to 23 months)	87 (4.9)	14 (16.1)	24 (27.6)	49 (56.3)
Children (2- 11 years)	74 (4.1)	6 (8.1)	13 (17.6)	55 (74.3)
Adolescents (12- 18 years)	62 (3.5)	5 (8.1)	7 (11.3)	50 (80.6)
Adult (18 years and older)	951 (53.2)	179 (18.8)	203 (21.3)	569 (59.8)
Adult (65 years and older)	553 (30.9)	132 (23.9)	120 (21.7)	301 (54.4)
Race- White	1125 (62.9)	208 (18.5)	241 (21.4)	676 (60.1)
Race- African American	459 (25.7)	109 (23.7)	93 (20.3)	257 (56)
Race-Other	91 (5.1)	10 (11)	18 (19.8)	63 (69.2)
Gender-Male	1076 (60.1)	211 (19.6)	216 (20.1)	649 (60.3)
Organisms in index blood culture				
Staphylococcus aureus	407 (22.8)	103 (25.3)	91 (22.4)	213 (52.3)
Enterococcus faecalis	156 (8.7)	30 (19.2)	41 (26.3)	85 (54.5)
Enterococcus faecium	123 (6.9)	10 (8.1)	15 (12.2)	98 (79.7)
Escherichia coli	269 (15)	42 (15.6)	50 (18.6)	177 (65.8)
Klebsiella pneumoniae	155 (8.7)	20 (12.9)	34 (21.9)	101 (65.2)
Pseudomonas aeruginosa	109 (6.1)	23 (21.1)	23 (21.1)	63 (57.8)
Enterobacter cloacae	83 (4.6)	14 (16.9)	16 (19.3)	53 (63.9)
Serratia marcescens	52 (2.9)	19 (36.5)	11 (21.2)	22 (42.3)
Candida species	175 (9.8)	26 (14.9)	41 (23.4)	108 (61.7)
Polymicrobial	179 (10)	27 (15.1)	28 (15.6)	124 (69.3)
Microbiology characteristics				
Matching blood culture in previous 14 days	127 (7.1)	15 (11.8)	22 (17.3)	90 (70.9)
Any positive non-commensal blood culture in previous 14 days	184 (10.3)	21 (11.4)	34 (18.5)	129 (70.1)
Positive non-commensal blood culture less than days after admission	127 (7.1)	16 (12.6)	18 (14.2)	93 (73.2)
Index blood culture days 4-7	618 (34.5)	127 (20.6)	140 (22.7)	351 (56.8)
Index blood culture days 8-14	505 (28.2)	109 (21.6)	104 (20.6)	292 (57.8)
Index blood culture days 15-21	259 (14.5)	49 (18.9)	46 (17.8)	164 (63.3)
Index blood culture days 22-28	114 (6.4)	18 (15.8)	25 (21.9)	71 (62.3)
Index blood culture day greater than 28	293 (16.4)	39 (13.3)	64 (21.8)	190 (64.8)
Clinical characteristics				
ICU stay 48 hours before index BC	579 (32.4)	122 (21.1)	118 (20.4)	339 (58.5)
Central line	1191 (66.6)	205 (17.2)	241 (20.2)	745 (62.6)

Mechanical ventilation	377 (21.1)	66 (17.5)	90 (23.9)	221 (58.6)
Urinary catheter	624 (34.9)	113 (18.1)	148 (23.7)	363 (58.2)
Surgery in past 30 days	533 (29.8)	137 (25.7)	132 (24.8)	264 (49.5)
Procedure in last 14 days	720 (40.2)	151 (21)	132 (18.3)	437 (60.7)
Active malignancy with ongoing chemotherapy	385 (21.5)	20 (5.2)	43 (11.2)	322 (83.6)
Received immunosuppressive or immunomodulator therapy	372 (20.8)	44 (11.8)	64 (17.2)	264 (71)
Long term immunosuppression	438 (24.5)	45 (10.3)	66 (15.1)	327 (74.7)
Cardiopulmonary resuscitation	96 (5.4)	14 (14.6)	25 (26)	57 (59.4)
Dialysis	324 (18.1)	63 (19.4)	68 (21)	193 (59.6)
Drug use	124 (6.9)	24 (19.4)	26 (21)	74 (59.7)
Current drug use	84 (4.7)	15 (17.9)	17 (20.2)	52 (61.9)
Injection or Skin popping	52 (2.9)	6 (11.5)	11 (21.2)	35 (67.3)
Stem or bone marrow transplant	179 (10)	1 (0.6)	17 (9.5)	161 (89.9)
Neutropenia	339 (18.9)	5 (1.5)	31 (9.1)	303 (89.4)
Solid organ transplant	132 (7.4)	23 (17.4)	28 (21.2)	81 (61.4)
Shock	460 (25.7)	79 (17.2)	84 (18.3)	297 (64.6)
Total parenteral nutrition	296 (16.5)	34 (11.5)	69 (23.3)	193 (65.2)
Trauma- blunt or penetrating	72 (4)	14 (19.4)	18 (25)	40 (55.6)
Sickle cell disease	16 (0.9)	4 (25)	2 (12.5)	10 (62.5)
Oncology unit	299 (16.7)	18 (6)	32 (10.7)	249 (83.3)
Source				
Gastrointestinal/Abdominal source	622 (34.8)	40 (6.4)	86 (13.8)	496 (79.7)
Gastro source with bowel translocation and neutropenia	194 (10.8)	0 (0)	5 (2.6)	189 (97.4)
Hepatobiliary source	90 (5)	6 (6.7)	11 (12.2)	73 (81.1)
Gastro source other	446 (24.9)	40 (9)	82 (18.4)	324 (72.6)
Endovascular source	563 (31.5)	173 (30.7)	139 (24.7)	251 (44.6)
Central line source	435 (24.3)	130 (29.9)	121 (27.8)	184 (42.3)
Intravascular catheter	488 (27.3)	166 (34)	129 (26.4)	193 (39.5)
Central line- tunneled and port	157 (8.8)	46 (29.3)	41 (26.1)	70 (44.6)
Peripherally inserted central catheter	155 (8.7)	51 (32.9)	44 (28.4)	60 (38.7)
Central line-temporary	132 (7.4)	38 (28.8)	35 (26.5)	59 (44.7)
Peripheral Intravascular	76 (4.2)	43 (56.6)	14 (18.4)	19 (25)
Respiratory source	208 (11.6)	25 (12)	71 (34.1)	112 (53.8)
Respiratory source with ventilator associated pneumonia	64 (3.6)	12 (18.8)	20 (31.3)	32 (50)
Respiratory source with non-ventilator pneumonia	111 (6.2)	11 (9.9)	38 (34.2)	62 (55.9)
Urinary source	176 (9.8)	48 (27.3)	46 (26.1)	82 (46.6)
Urinary source with urinary catheter	64 (3.6)	30 (46.9)	15 (23.4)	19 (29.7)
Skin and soft tissue source	157 (8.8)	46 (29.3)	34 (21.7)	77 (49)
Surgical site infection source	102 (5.7)	32 (31.4)	30 (29.4)	40 (39.2)
Bone and Joint source	84 (4.7)	10 (11.9)	10 (11.9)	64 (76.2)
Central nervous source	20 (1.1)	3 (15)	0 (0)	17 (85)
Reproductive source	19 (1.1)	5 (26.3)	5 (26.3)	9 (47.4)
Other source	58 (3.2)	13 (22.4)	14 (24.1)	31 (53.4)
No source	312 (17.4)	20 (6.4)	82 (26.3)	210 (67.3)

Contaminant	60 (3.4)	26 (43.3)	15 (25)	19 (31.7)

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