A Cox-proportional Hazards Model for Predicting Nosocomial Bloodstream Infections From the Clinical Electronic Medical Record

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ABSTRACT:

Previous studies identifying risk factors for nosocomial blood stream infections (BSI) have relied on labor-intensive chart review. The electronic medical record (EMR) can provide real-time data for profiling patients at risk for BSI. We used our hospital EMR to study risk factors for nosocomial BSI from 6/01-6/02. Using CDC definitions for BSI, we pulled a number of variables from the EMR data repository including demographics, medications, nutritional status, presence of diabetes (DM), skin/wound status, and use of ventilator, urinary catheter, or central/arterial/PICC catheter. We developed a Cox Proportional Hazards model with half the cohort (14,977 controls and 123 BSI cases). Final variables chosen by clinical relevance, significance on univariate analysis and by step-wise automated selection to include confounders. The model contained: use of antibiotics (HR 4.6), central venous catheter for 0-6 days (HR 1.8), central venous catheter for greater or equal to 7 days (HR 1.3), tunneled central venous port (HR 9.3) and DM (HR 2.1). Variables from multivariate analysis were used for the predictive index; points were derived from the respective HR of the Cox model. A cutoff value that maximized sensitivity (75%) and specificity (89%) had a positive predictive value (PPV) of .05. This model was validated on the second half of the cohort (122 BSI, 14,977 'non-cases') with resultant sensitivity of 69%, specificity of 88% and PPV of 0.05 (no significant differences in the sensitivity, specificity and PPV).

Conclusion: We successfully used a hospital-based EMR in developing a Cox Proportional Hazards model for nosocomial BSI. This model was used to derive a predictive index. At a cutoff point providing a sensitivity of 75% and specificity of 89% for finding patients who develop nosocomial BSI, the index had a PPV 0.05.

Background:

The electronic medical record (EMR) provides an opportunity for real-time risk modeling of nosocomial blood stream infections (BSI).

Prior Studies have identified BSI risk factor by conventional chart review

Conventional chart review is labor-intensive and may not allow for intervention to prevent development of BSI in susceptible patients

Methods:

Variables extracted from EMR
- -Demographics
- -Medication
- -Immunosuppression + DM
- -Nutritional status
- -Ventilator use
- -Urinary Catheter
- -Skin wound status
- -Mental status
- -CVC/PICC/Arterial Cath.

Cox Proportional Hazards Model derived from ½ of cohort

Predictive model and scoring system derived from Cox proportional hazards model

Predictive model validated on other ½ cohort

Model tested for internal validity

BSI Definition

CDC Criteria:
Newly positive blood culture 48 hours post admission

Capture **1st episode** of nosocomial BSI

Exclude:
patients with positive blood cultures within the first 48 hours

Patients with same organism bacteremia pre and post 48 hours

Coagulase negative **staphylococci**

Sunrise Critical Care v1.3 (Eclipsys Corp)

100% nursing, nutrition, respiratory therapy documentation

100% physician order entry

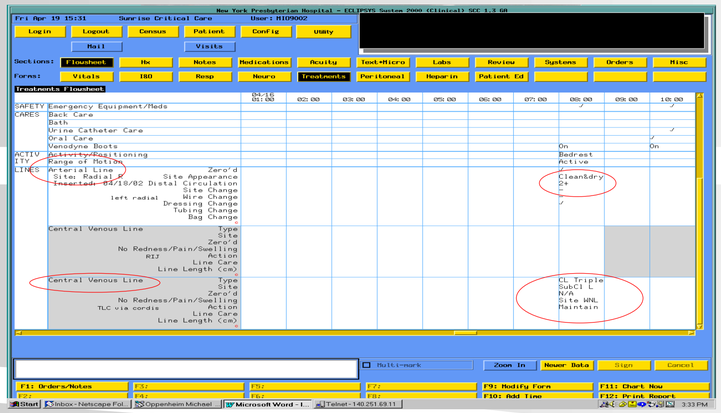
Pharmacy records of all medications during LOS

Laboratory, microbiology, pathology, and radiology records

Data is entered in discrete form and free text

Clinical data repository

EMR Screen Reprint: Invasive Catheters



Results:

Total Cohort
- 245 distinct NBSI cases
- 29,954 "non cases"

Test Cohort
- 123 distinct NBSI cases
- 14,977 "non cases"

Validation Cohort
- 122 distinct NBSI cases
- 14,977 "non cases"

Multivariate Model from Test Cohort

-Variables chosen by clinical relevance, significance on univariate analysis and by SAS step-wise selection

-Catheter GE 7D non-significance likely due to lack of power but retained due to pathophysiologic plausibility

Variable	Hazard Ratio	P value
Antimicrobial	4.6	<0.0001
CVC for 1-6 days	1.8	0.0178
CVC for > 7 days	1.3	0.3297
Tunneled CVC for > 7 days	9.3	<0.0001
Diabetes Mellitus	2.1	0.0002

Multivariate HR: TCVP>Antibiotics>DM> Catheter 0-6> catheter GE 7D

Predictive Model

End Point= NBSI: Score ranges from 0- 17. Positive Trend in PV + with increasing score. 5 Point cut-off to maximize sensitivity and specificity

Score=5*antimicrobialscat+2*ctotalfgt0lt7+2*ctotalfge7+2*antidbscat+11*TCVPfge7

Score	With Event	Without Event	Cutoff (if <= value, no risk)	PV+	Sensitivity	Specificity
0	3	8637	0	0.019	0.976	0.577
2	8	1425	2	0.022	0.911	0.672
4	2	85	4	0.022	0.895	0.678
5	**18**	**3103**	**5**	**0.051**	**0.750**	**0.885**
7	39	1300	7	0.113	0.435	0.972
9	44	398	9	0.294	0.081	0.998
13	0	3	13	0.323	0.081	0.999
18	8	13	18	0.200	0.016	0.999
20	2	8	20			

Validation Model

End Point= NBSI: Score ranges from 0- 17. Positive Trend in PV + with increasing score. 5 Point cut-off to maximize sensitivity and specificity

Score=5*antimicrobialscat+2*ctotalfgt0lt7+1*ctotalfge7+2*antidbscat+9*TCVPfge7

Score	With Event	Without Event	Cutoff if >	PV+	Sensitivity	Specificity
0	6	8565	0	0.018	0.950	0.572
1	5	156	1	0.017	0.909	0.582
2	2	1297	2	0.021	0.893	0.669
3	3	23	3	0.021	0.868	0.670
4	0	74	4	0.021	0.868	0.675
5	**21**	**3108**	**5**	**0.046**	**0.694**	**0.883**
6	10	180	6	0.045	0.612	0.895
7	34	1153	7	0.086	0.331	0.972
8	16	178	8	0.088	0.198	0.983
9	18	207	9	0.125	0.050	0.997
10	0	9	10	0.154	0.050	0.998
12	0	4	12	0.171	0.050	0.998
15	4	19	15	0.167	0.017	0.999
17	2	10	17			

Chi-Square Test: Internal Validity

Parameter	Test Statistic	P Value
PPV	0.6425	0.422
Sensitivity	0.9504	0.3296
Specificity	0.4382	0.5080

Statistical comparison between the predictive model and the validation cohort reveals NO statistically significant differences in Sensitivity, Specificity, or PPV.

Conclusion:
- Study goal was to use the EMR to identify patients at high risk for nosocomial BSI using automated systems
- Data was successfully extracted for 245 NBSI and 29,954 non-BSI patients
- This cohort was randomly divided in half in order to develop a predictive model for NBSI
- The predictive model was ***internally*** validated on the second half of the cohort.
- The model is ***preliminary*** and must be ***prospectively*** validated