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Triage Algorithm for Chest Radiography for Community-Acquired Pneumonia of Emergency Department Patients: Missing Data Cripples Research

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Novometric analysis[1,2] is used to develop a triage algorithm for rapid ordering of chest radiography for community-acquired pneumonia (CAP), for a retrospective Emergency Department-based matched case-control study[3] providing data on attributes assessed for 100 radiographic confirmed cases of both CAP and influenza-like illness (ILI). Results for the least complex model revealed intake temperature exceeding 99.25°F was 73.9% sensitive [exact discrete 95% confidence interval (CI): 62.5-84.4%] and 67.9% specific (95% CI: 57.1-78.3%). Analysis was compromised by missing data so novometry was conducted omitting structural decomposition analysis in order to evaluate underlying potential of the attributes. Findings illustrate how missing data limit the fruitfulness of empirical research.

The initial analysis performed on these data[3] by automated classification tree analysis[4,5] (CTA) occurred prior to the development of novometric theory.[1,2] Accordingly, data for 100 Emergency Department (ED) patients with confirmed CAP and 100 with confirmed ILI were reanalyzed using current methods.[1,2] Structural decomposition analysis[1] (SDA) identified two attributes for inclusion in CTA: a continuous measure of temperature (°F), and a binary indicator of dyspnea. The minimum denominator search algorithm[1] (MDSA) identified a descendant family of two unique CTA models within which the globally optimal[1] (GO) model resides, and exact discrete 95% confidence intervals[1] (CIs) were computed for model and chance classification performance. Model 1 used both ratings, and model 2 used only patient intake temperature (Table 1). As seen, comparison of 95% CIs for model and error performance indicates both models achieved statistically reliable classification. And, comparison of model 95% CIs reveals the ESS (accuracy) and Efficiency (parsimony) were statistically comparable across both models. The efficiency of model 1 is 46.8% of theoretical ideal, and the efficiency of model 2 is 41.4% of theoretical ideal.[1]

2155-0182/10/$3.00

Table 1: Summary of MDSA Procedure for Discriminating CAP and ILI Patients

Step	Strata	MinD	ESS	Efficiency
1	4	37	46.9	11.7
			30.9-62.4	7.72-15.6
			0.82-15.4	0.21-3.84
2	2	88	41.4	20.7
			26.0-56.5	13.0-28.2
			0.19-14.2	0.10-7.12

Note: There were two steps in this MDSA. Strata is the number of partitions identified by the CTA model. MinD is the smallest number of observations (patients) in any of the strata (i.e., the smallest model endpoint N). ESS is a normed index of classification accuracy on which 0 represents the level of accuracy expected by chance and 100 represents perfect (errorless) classification. By rule-of-thumb: ESS<25 is a relatively weak effect; ESS<50 is a moderate effect; ESS<75 is a relatively strong effect; and ESS>75 is a very strong effect.[6] Efficiency, an index of parsimony, is ESS/number of strata. Under the ESS and Efficiency point estimates, the first row is the exact discrete 95% CI for the model, and the second row is the corresponding 95% CI for chance.

Figure 1 presents the elemental two-strata UniODA[6,7] model 2, and Figure 2 shows the more complex four-strata CTA[4,5] model 1.

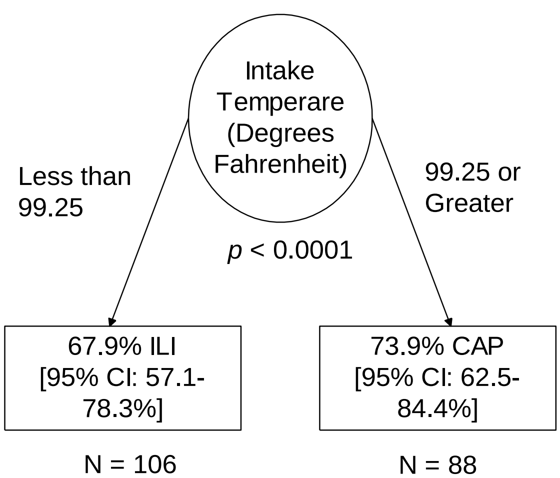

Figure 1: Two-Strata Model for Discriminating CAP and ILI Patients

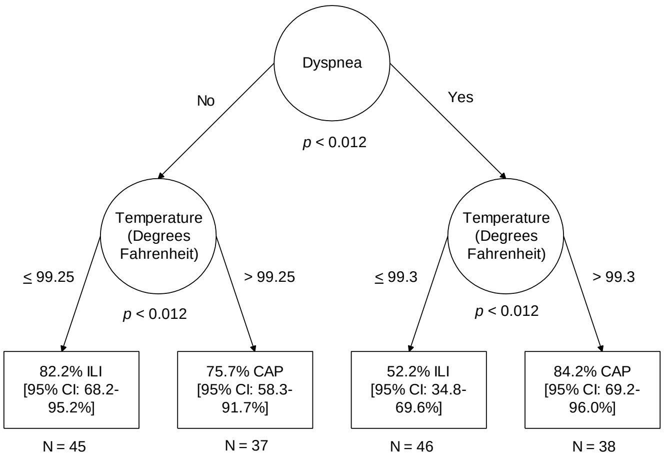

Figure 2: Four-Strata Model for Discriminating CAP and ILI Patients

As seen, the two ILI model endpoints are redundant[8] in the four-strata model, as are the two CAP model endpoints. Therefore, the two-strata model (Figure 1) is selected as the GO model for this application. Figure 3 presents the corresponding triage screening algorithm for ordering chest radiography for CAP in the ED.

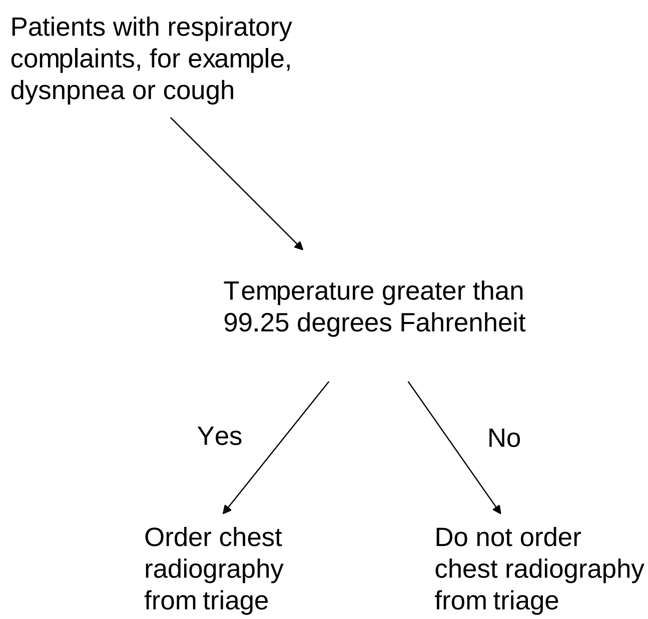

Figure 3: Triage Screening Algorithm for Ordering Chest Radiography for CAP in the ED

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Exploratory Novometry

In the prior analysis SDA was used to identify attributes to analyze in MDSA. In SDA, several attributes with greater ESS than the attribute which was actually selected were identified, which had substantially smaller N than the selected attribute. These larger ESS and smaller N attributes were omitted because they drop-out of the solution as the MDSA minimum denominator increases.[1] Several attributes had a moderate to strong value for ESS[6], but they also had very small N due to many missing values. Exploratory novometric analysis was thus performed by omitting SDA, in order to assess whether a superior GO model might have been identified had the missing data instead been complete.[1] Summarized in Table 2, a descendant family of 14 unique CTA models was identified: analysis terminated with the two-strata GO model identified in initial confirmatory analysis.

Table 2: Summary of Exploratory MDSA for Discriminating CAP and ILI Patients

Step	Strata	MinD	ESS	Efficiency
1	8	2	95.0 80.0-100 0.83-20.0	11.9 10.0-12.5 0.10-2.50
2	6	6	89.4 74.3-100 0.00-19.2	14.9 12.4-16.7 0.00-3.20
3	5	7	81.1 64.2-94.1 0.00-19.2	16.2 12.8-18.8 0.00-3.84
4	4	9	72.4 45.6-94.1 1.89-29.7	18.1 11.4-23.5 0.47-7.42
5	6	11	77.6 64.6-88.9 0.88-17.5	12.9 10.8-14.8 0.15-2.92
6	4	18	69.3 53.8-83.3 1.65-19.2	17.3 13.4-20.8 0.41-4.80
7	4	19	63.9 47.9-78.4 1.57-18.8	16.0 12.0-19.6 0.39-4.70
8	4	21	57.7 40.8-73.7 0.28-17.8	14.4 10.2-18.4 0.07-4.46
9	4	21	56.7 35.3-75.0 1.67-22.8	14.2 8.82-18.8 0.42-5.70
10	3	30	54.0 43.1-54.0 0.30-20.6	12.2 14.4-18.0 0.10-6.87
11	4	35	50.9 35.1-66.3 0.27-14.7	12.7 8.78-16.6 0.07-3.68
12	4	42	50.7 35.0-65.6 1.02-14.7	12.7 8.75-16.4 0.26-3.68
13	3	45	43.8 28.3-58.8 0.75-14.3	14.6 9.44-19.6 0.25-4.77
14	2	88	41.4 26.0-56.5 0.19-14.2	20.7 13.0-28.2 0.10-7.12

Note: There were 14 steps in this MDSA. See Note to Table 1.

Models 1-5 violate the first axiom of novometric theory[1] because the minimum denominator is too small to provide adequate statistical power.[9] Models 6-9 have sufficient minimum denominators to justify two-strata models, and thus all of these models are over-determined (i.e., employ more strata than are justified from a statistical power perspective). Only models 13 and 14 have minimum denominators sufficiently large to justify the number of strata identified.[9] Comparison of model 95% CIs reveals the ESS (accuracy) of models 1-3 and 5 was significantly greater than for models 10, 13 and 14. And, comparison of model 95% CIs also reveals the efficiency (parsimony) of models 3, 6, 10 and 14 was significantly greater than for model 1.

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Table 3 provides descriptive information on all 13 exploratory models. For the four-strata confirmatory model (Table 1) these data were N=166; Attributes=2; CAP=66.7; ILI= 80.3; and % Ideal=46.8. For the GO model, N=194.

Table 3: Descriptive Information for Exploratory Models

Model	N	Attributes	CAP	ILI	% Ideal
1	92	5	100	95.0	95.2
2	92	4	94.4	95.0	89.4
3	92	3	95.0	86.1	81.0
4	49	3	84.8	87.5	72.4
5	133	4	82.9	94.7	77.4
6	111	3	75.0	94.3	69.2
7	123	3	72.4	91.5	64.0
8	138	3	75.9	81.8	57.6
9	95	2	66.2	90.5	56.8
10	111	2	54.0	100	36.6
11	167	3	75.6	75.3	50.8
12	178	3	72.5	78.2	50.8
13	186	2	79.0	64.8	43.8

Note: N=total sample size; Attributes=number of different attributes used in the model; CAP=% correctly classified CAP patients (“sensitivity”); ILI=% correctly classified ILI patients (“specificity”); and % Ideal=percentage of theoretically ideal efficiency[1].

Finally, Table 4 lists the attributes (and number of missing values) used in all 13 exploratory models. Perhaps the most informative attribute with excessive missing values was white blood cell count. Models 1-3 and 5-9 included white blood cell count and temperature as attributes, and ranked as the most accurate models which were identified in exploratory analysis. Replication of these findings with complete data is warranted.

Table 4: Attributes and Number of Missing Values used by Exploratory Models

Attribute	Models	N Missing
WBC	1-10	105
Temperature	1-3, 5-9, 11-13	6
Pulse Oximetry	1,2,13	12
Dyspnea	1-3, 8, 11	29
Respiration Rate	1, 7	7
Sore Throat	4	122
Fever	4, 5, 12	20
Heart Rate	5, 11, 12	6
Wheezing	6, 10	1

Note: WBC=White Blood Cell count. Fever=binary indicator of whether temperature exceeded 100.4 degrees Fahrenheit.

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