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"Identification of Patterns in Diagnostic Attributes
in Skull Trauma Cases Using An Entropy Minimax Approach"

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Identification of Patterns in Diagnostic Attributes in
Skull Trauma Cases Using an Entropy Minimax Approach

Christensen* has previously demonstrated the elements of a relatively new technique concerning the discovery of patterns in data by the application of an entropy minimax principle. The purpose of my presentation is to offer for your consideration the results which we obtained when we applied this technique to a body of particularly interesting radiological data. To understand the basis of our interest, it is necessary to withdraw momentarily from the details concerning both the method and the data and to look briefly at the larger question of the doctor's motivation for obtaining a radiological examination, or for that matter a doctor's motivation in using any diagnostic process.

As shown in Figure 1 there are basically three reasons which would explain why a doctor may be interested in using a particular diagnostic procedure. These reasons, not necessarily listed in the order of their importance, are: 1) to benefit the patient, 2) to satisfy the physician's research aims and 3) to protect the physician from legal repercussions. A significant amount of work has already been completed concerning the assessment of these various motivations, with special interest devoted to two questions. The initial question regards the degree to which the physician may be motivated to use a radiological diagnostic process as either a research tool or simply because of its novelty. These studies have already been made by Potchen⁵ and others. Their findings indicate that the majority of new diagnostic processes which do not contribute

*References 1, 2, 3, 4.

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significantly to patient care in fact undergo a form of product life cycle whereby their use peaks out and then gradually tails off as physicians discover that the novel diagnostic process does not really contribute to patient care. Potchen has determined that the costs involved in this particular motivation for the use of radiological processes are relatively small and probably not of great overall importance.

The second question concerns the degree to which diagnostic processes are used in a defensive manner, that is, to protect the physician from medical-legal problems. Again, Potchen and Twine⁶ have investigated this particular use of diagnostic procedures in some detail. They find the following rather disturbing facts: The current estimate regarding the size of the total market for diagnostic radiology in the United States is approximately \$4 billion dollars per year. Fractional estimates of this amount which could be attributed to the defensive use of radiological process run from a low of 10% to a high of 30%. Thus, we are talking numbers on the order of \$400 million dollars at a minimum, to something on the order of \$1.3 billion dollars at a maximum. The interesting aspect regarding these numbers is the fact that even at the minimum number, namely the \$400 million dollars, the expenditure is totally out of proportion with the actual amount of settlements which have resulted from malpractice suits, especially malpractice suits involving the failure to use a radiological diagnostic process. Thus, Potchen and Twine conclude that there is a substantial overutilization of radiological diagnostic procedures, when in fact, such utilization is not justifiable on any risk assessment basis.

There are two interesting points we should note here. The initial point is that it is entirely possible that there are excessive numbers of radiological examinations being performed, and that this excess is due in part to the desire by physicians to protect themselves against medical-legal actions. The second point is this: there is a definite requirement for some mechanism by which one could obtain a relatively hard scientific measure of the efficacy of a diagnostic process. If such a procedure could be found and its validity demonstrated, it would greatly contribute to making certain that health care standards are established on the basis of patient benefit, as opposed to other mainly medical-legal considerations. Thus, the principal objective in our work was to contribute to the creation of just such a procedure.

With this objective in mind, Doctor Potchen and I set out to construct a conceptual model for the measurement of efficacy. Figure 2 is an attempt to diagram that model in a schematic form. On the left, we have shown the diagnostic activities which a physician undertakes. These can include anything as simple as a visual observation, to relatively sophisticated diagnostic procedures involving a great deal of time, preparation and possibly expensive equipment. These procedures and observations generate a set of data which we call patient attributes. These attributes can be quite accurately measured. The box labeled "Utility" is meant to convey the physician's perceptions of precisely what the various diagnostic attributes have told him. In that box, he is acting as an information interpretation device. Once he has observed these diagnostic attributes, he takes a particular action and again that action can be very well documented. The action

can consist of ordering further diagnostic tests, dismissing the patient, or treating the patient with some particular form of therapy. We have lumped all of these actions together for the purpose of simplicity and have simply shown them all as contributing to what we call efficacy. Finally, the patient's perception of what the doctor has done for him, ultimately defines efficacy.

In Figure 3, we define diagnostic efficacy as the beneficial effect of a diagnostic procedure on the course of a disease as measured by the degree of change from random variations in the natural history of the disease. Our analytical tools are not yet sufficiently developed, nor does the data exist to permit an evaluation of this particular quantity at this time. However, in Figure 4 we present a quantity which we believe can in fact be measured in quantitative fashion.

This quantity we call diagnostic utility and we define it as follows: The effect of a diagnostic procedure on what a physician does for a patient as measured by the physician's actions in response to the outcome of the diagnostic procedure. All of the parameters necessary to measure diagnostic utility can in fact be obtained in hard quantitative form. The fundamental problem is to define a method by which one can actually relate these various parameters to obtain some useful measure of diagnostic utility.

In Figure 5 we show a number of possible ways one might go about obtaining a useful measure of diagnostic utility, and ultimately, of efficacy. On the left hand side we indicate a separation of methods based upon whether one is interested in studying individual cases, or whether one is interested in creating an aggregate statistical

model. On the top we separate the methods according to whether or not they are structured or totally unstructured. The criteria which determines whether the model is structured or unstructured is the degree to which the model introduces a priori assumptions. The entries at the top of the matrix basically involve data analysis techniques such as systems dynamics approaches and likelihood ratio decision models. Unfortunately, these models are not well adapted to handling aggregate data. Consequently, we were forced to examine either the use of classical Bayesian statistical approaches or alternatively, a totally unstructured approach based on information theory. A number of authors such as Lusted⁷ and Feinstein⁸ have worked with the classical Bayesian approach in the analysis of clinical data. However, as Christensen has pointed out previously, the difficulty with this approach is that it ultimately relies on the determination of basic a priori probabilities. Consequently, studies based on classical Bayesian approaches have not been overly successful in treating large amounts of statistical data. Thus, we arrived at the conclusion that a more powerful technique such as entropy minimax was required in order to analyse the type of data which we had obtained.

In Figure 6 we state in as simple terms as possible, the definition of a pattern and in particular of a pattern in diagnostic data. Basically, it is an arrangement of subsets of attributes, in this case the results of diagnostic tests, such that the receipt of one additional event not in the original data set will convey to the investigator, in this case the physician, a minimum amount of information.

With this in mind, we return briefly to our original model. As Figure 7 shows, the particular data which we have obtained consists

of a number of diagnostic attributes pertaining to each of a large number of patients. In addition, we have for each patient the observed action of the physician. What we show is that the entropy minimax methods of pattern discovery will not only recreate a set of attribute patterns which are quite typical of clinical practice, but in addition, will identify certain diagnostic attributes as, in fact, contributing little or nothing to the actual observable outcome, and therefore, having no diagnostic utility.

The primary source of our data is illustrated in Figures 8 and 9. Figure 8 shows the first page of a two page questionnaire which was used in a hospital emergency room setting to obtain information on each patient for whom a skull x-ray was to be ordered. These questionnaires were filled out in two hospitals in the Seattle, Washington area, for a period of time lasting approximately one year. The data were originally collected by Dr. John Loop⁹ of the University of Washington and verified for completeness and accuracy by members of Dr. Loop's staff. A total number of questionnaires in excess of 1,500 were collected and verified over the period of time which the study lasted.

As Figure 9 indicates, the questionnaire is essentially a prospective questionnaire in which the doctor is asked to provide his best estimate of the probability of finding a skull fracture in this particular patient, based only on the information shown in the preceding figure. In addition, the doctor was asked to check off his reason for requesting the skull x-ray. After the x-ray had been taken, the radiologist was asked to check off the appropriate

data at the bottom of the form. For our purposes we were specifically interested in whether or not the x-rays showed evidence of a skull fracture.

The data from each questionnaire was transcribed by members of Dr. Loop's staff into punch card form and provided to Dr. Potchen and myself in conjunction with a study then being undertaken by the American College of Radiology. In Figure 10, we show the list of 24 attributes which we used in our initial investigations.

As Figure 11 indicates, in our first computer run we sought the patterns of attributes which would act as predictors for the actual outcome of the radiographic examination. For reasons of experimental convenience, we limited our first run to a total of 400 of the original 1500 samples. Specifically, we chose 200 samples in which we knew for a fact that the x-ray had indicated the existence of a skull fracture. The remaining 200 samples we chose at random from the remaining patients, none of whom were shown to have skull fractures. This strategy allowed us to utilize equal a priori probabilities in these initial investigations.

One of the difficulties we encountered in utilizing this particular technique, was finding a mechanism by which we could present the results and in particular, a mechanism that would be readily understood by non-mathematicians. Unfortunately, I have to relate that we were not altogether successful. Figure 12 is representative of the format finally evolved. At this point I should note that the version of the program which we were using involved a step-wise approximation to the pattern discovery problem. Consequently, the individual cells were defined in a sequential manner. This data

happens to relate to Step No. 3 from Run No. 1. This particular run developed a total of 18 individual cells which completely span the input data set of approximately 400 patients. The vertical axis on the graph gives the value of the estimated outcome probability.

Underneath the graph, you will note a cell definition stating which attributes are to have which values in order for a particular event to be considered part of this particular cell. In simple clinical terms, what this particular graph tells us is the following: if both an ear discharge and ear drum discoloration are present and there is no sensory abnormality, a physician will assign a priori odds of 10 to 1 in favor of a skull fracture with probability of 47%.

Likewise, other physicians will assign odds of at least 50-50 with a probability of 40%. On the other hand, given these attributes, the probability that a physician will think that the odds of a fracture are relatively small, say 1 to 10, is only .07. Thus, the conclusion is that a physician, presented with just these three attributes, would be highly likely to predict that this particular patient would in fact have a skull fracture. As a cross check on the program, Dr. Potchen and I took the total of 18 cells which the program had defined and generated graphs for each of those cells. We then asked various physicians to comment as to whether or not the cell definitions and the attribute complexes agreed, in general at least, with their own subjective odds assignments. The response was that the cell definitions did in fact make sense from a clinical point of view. Thus, we conclude that in Run Number 1, the program was in fact able to pick out a pattern which agreed quite closely with accepted standards of practice.

We next made a run in which we correlated the individual attributes against the actual outcome of the x-ray itself for the same 400 patient sample. In this particular case, we noted what seems to be a better quality of cell definition. In other words, the program was able to sort the events into cells which achieved a greater separation from the a priori probabilities than had been the case when we used the physician's subjective odds as the outcomes. Figure 13 is an example of the particular cells defined in this second run. Again, we made a complete set of graphs for this particular run, which number 16 cells, and showed these to various physicians, asking again for their comments. If anything, they felt on a subjective basis that the cells defined by Run Number 2 were in fact more realistic than the cells defined by Run Number 1.

Figure 14 is an attempt to summarize the complete results from Run Number 1. We see from this figure that there were a total of 18 of the original 24 attributes which appeared as primary attributes in cell definitions in this run. Of greater interest, we note that there were six attributes which apparently had absolutely no effect on the physician in his assignment of a priori odds to find a skull fracture.

We made up a similar presentation of the attributes which were found to be correlated with the presence of a skull fracture in the x-ray film. In Figure 15, we present the results of the previous figure on the left-hand side and for comparison's sake, we present the results of correlation of the x-ray outcome on the right-hand side. Strictly speaking, the entropy minimax pattern discovery technique does not assign relative weight or importances to various attributes. However, in the step-wise approximation program there is in effect a

built-in ordering of the importance of the various attributes. We were made aware of this by the physicians who examined this display and stated that in their opinion the listed attributes on the right-hand side, namely those correlated with the x-ray outcome, had what they considered to be the more reasonable order in terms of the subjective importance which they themselves would apply to observing each of these particular attributes. At the bottom of the figure, we noted that the last two items on the right and on the left, namely, Babinski and visual disturbance, had absolutely no effect on the cell definitions in either case. Consequently, we concluded that these items had no diagnostic utility.

In the previous run, we had chosen the data sample in a manner such that the actual probability of drawing a fracture case from the sample would agree with a uniform a priori probability of finding a skull fracture in a typical emergency room setting. This probability has been variously estimated as being somewhere between 10 and 17 percent. Our objective here was to see whether the program, when presented with a set of data that reflected this realistic a priori probability, would come out roughly with the same set of criteria as far as the cell definitions were concerned. Owing to program limitations, we could not handle the entire set of 24 attributes. Consequently, in Figure 16 we eliminated the six least important attributes shown on the previous figure. We then reran the program. Aside from a slight reordering of the attributes, we were gratified to note that the cell definitions were not dramatically altered, and that all of the attributes which had previously been identified as being of critical importance again appeared as being highly correlated with the respective outcomes.

I return briefly to Figure 11 in order to give an interesting result which appeared when we attempted to correlate the attributes already reviewed with the second outcome on the screen, namely the reason for ordering the x-ray. We noted that there was essentially no correlation between sets of attributes and any of the outcomes which you see listed under reasons for requesting the x-ray. This result would seem to indicate that a substantial number of x-rays in this particular data sample were ordered for reasons other than those that might be suggested to the physician by his observation of the patient. In short, we may be seeing a form of indirect evidence of the extensive use of x-ray procedures for defensive purposes.

Returning now to the results we have seen in our first two runs, a comparison of two cells was shown which, upon detailed examination, were found to contain nearly the same collection of patient cases. On the left-hand side of Figure 17 we see that the physician's subjective probability of considering the possibility of the skull fracture being likely is on the order of .09. On the other hand, the actual analysis of the outcomes of the x-rays indicates that the probability of a fracture is in fact on the order of .06. A detailed analysis of a number of such comparisons of cells in which the probability of a fracture was small, indicated that the physician tended to act uniformly on the conservative side. That is to say, that regardless of how certain he might reasonably be that there is in fact no skull fracture, he nonetheless tended to assign odds somewhat higher than those justifiable by hard statistical evidence. One could argue that this is in fact perfectly consistent with a conservative outlook intended for the patient's own good.

With this in mind, we were somewhat surprised by the results shown in the next figure.

In Figure 18 the results on the right indicate that the probability of a fracture is extremely high, given the cell definition shown. On the other hand, the results on the left indicate that the physician does not subjectively rate the possibility of a skull fracture as being as high as it actually is. At this point, one is a little bit at a loss to hypothesize a behavioral model which would explain this type of result.

Since the implementation of the entropy minimax method which we were using was a stepwise approximation to the ideal program, I thought it would be interesting to show the behavior of the program as it processes its way through a particular set of data. The graph of Figure 19 shows the number of events contained in each cell as the program steps through the data, and we note that the number of events in each cell tends to fall off in a roughly logarithmic manner. This sort of behavior tended to be fairly consistent throughout all of the runs that we did.

Figure 20 indicates that as the program works its way through the data, the sharpness with which each successive cell is able to redefine a priori probabilities tends to diminish and gradually converges toward the original a priori probability level. This data corresponds with the data shown in the previous figure. And again, this particular behavior was consistent throughout all of our runs.

FACTORS WHICH EFFECT A PHYSICIANS DECISION TO USE A DIAGNOSTIC PROCEDURE

A MODEL OF THE INFORMATION FLOW DEFINING THE DIAGNOSTIC PROCESS

DIAGNOSTIC EFFICACY IS DEFINED AS:

THE BENEFICIAL EFFECT OF A DIAGNOSTIC
PROCEDURE ON THE COURSE OF A DISEASE,
MEASURED BY THE DEGREE OF CHANGE FROM
RANDOM VARIATIONS IN THE "NATURAL
HISTORY" OF THE DISEASE.

DIAGNOSTIC UTILITY IS DEFINED AS:

THE EFFECT OF A DIAGNOSTIC PROCEDURE ON
WHAT A PHYSICIAN DOES FOR A PATIENT AS
MEASURED BY THE PHYSICIAN'S ACTIONS IN
RESPONSE TO THE OUTCOME OF THE PROCEDURE.

	TYPE OF MODEL	
	<u>Structured</u>	<u>Unstructured</u>
Degree of Data Aggregation	Some A Priori Assumptions Introduced by Model	Minimal A Priori Assumptions No Model Implied by Method
Micro: Individual Case Studies	Approaches based on various behavioral models	Techniques related to signal detection theory
Macro: Aggregated Statistical Data	Classical Bayesian Statistical approach combined with Boolean Logical structure	Methods based on information theory

MATRIX OF POSSIBLE APPROACHES TO THE
PROBLEM OF STUDYING EFFICACY

THE ENTROPY MINIMAX CONTEXT IS DEFINED AS:

AN ARRANGEMENT OF SUBSETS OF ATTRIBUTES
SUCH THAT THE RECEIPT OF ONE ADDITIONAL
EVENT NOT IN THE ORIGINAL DATA SET WILL
CONVEY TO THE INVESTIGATOR A MINIMUM
AMOUNT OF INFORMATION.

A MODEL OF THE INFORMATION FLOW DEFINING THE DIAGNOSTIC PROCESS

HEAD TRAUMA EVALUATION STUDY QUESTIONNAIRE

GENERAL INFORMATION

Hospital
Patient Number
Sex
Age Estimate

-
1. Male 2. Female
1. Newborn 2. Less than 1 yr. 3. 1-3 yrs
4. 4-12 yrs. 5. 13-20 yrs. 6. 21-45 yrs
7. 46-65 yrs. 8. Over 65 yrs.

HISTORICAL DATA

Unconsciousness

1. None 2. Less than 5 minutes 3. More than 5 min.

Retrograde Amnesia

1. None 2. Less than 5 min. 3. More than 5 min.

Confusion or Drowsiness

1. Yes 2. No

Visual Disturbance

1. Yes 2. No

Other Focal Sign

1. Yes 2. No

Vomiting

1. Yes 2. No

Headache

1. Yes 2. No

Seizure

1. Yes 2. No

Circumstances of Injury

1. Traffic accident 2. At home 3. At work 4. Fist fight 5. Sports 6. Gun shot wound 7. Other

Time since Injury

1. Minutes 2. Few hours 3. Many hours 4. Days 5. Weeks 6. Months 7. Years

Your Evaluation of the Injury

1. Trivial 2. Mild 3. Moderate 4. Severe

PHYSICAL EXAMINATION -
EVIDENCE OF TRAUMA

Hematoma

1. Yes 2. No

Laceration

1. Yes 2. No

Swelling

1. Yes 2. No

Palpable Bony

Malalignment

1. Yes 2. No

Nose: Discharge

1. Yes 2. No

Ear: Discharge

1. Yes 2. No

Ear: Drum Discoloration

1. None 2. Unilateral 3. Bilateral

Eye: Ecchymosis

1. None 2. Unilateral 3. Bilateral

TABLE III-1 (Continued)

PHYSICAL EXAMINATION -
NEUROLOGICAL EXAM

- State of Conscious-
ness (55) 1. Normal 2. Dazed 3. Stuporous
4. Semi-conscious 5. Comatose
- Breathing (57) 1. Normal 2. Irregular 3. Apnea
- Focal Weakness (59) 1. Yes 2. No
- Babinski (61) 1. Yes 2. No
- Other Reflex Abnor-
mality (63) 1. Yes 2. No
- Sensory Abnormality (65) 1. Yes 2. No
- Anisocoria (67) 1. Yes 2. No
- Other Cranial Nerve
Abnormality (69) 1. Yes 2. No
- Evidence of Intoxi-
cation (71) 1. Yes 2. No
- What do you feel are
the odds that this
patient has a skull
fracture or mid-line
shift? (73) 1. 9:1 certain 2. 50:50 3. 1 chance in 10
- What is your primary
reason for ordering
skull films? (75) 1. Fracture or mid-line shift seriously
suspected
2. Difficulty evaluating the patient
clinically
3. "Medical-legal" reasons
4. X-ray examination requested by the
patient or relative

Your Signature: _____

TO BE COMPLETED BY A RADIOLOGIST

- Evaluate the Pireal (77) 1. Not calcified 2. Normal position
3. Significantly shifted

Is there evidence
for a skull frac-
ture:

- (79) 1. Yes 2. No

ATTRIBUTES AND OUTCOMES USED IN THE

24 VARIABLE RUNS 1 AND 2

Attributes

<u>Bits</u>	<u>Name</u>		
1	Consciousness	Yes=1	No=0
1	Retrograde Amnesia	Yes=1	No=0
1	Drowsiness	Yes=1	No=0
1	Visual Disturbance	Yes=1	No=0
1	Other Focal Sign	Yes=1	No=0
1	Vomiting	Yes=1	No=0
1	Headache	Yes=1	No=0
1	Seizure	Yes=1	No=0
1	Hematoma	Yes=1	No=0
1	Swelling	Yes=1	No=0
1	Palpable Bony Malalignment	Yes=1	No=0
1	Nose Discharge	Yes=1	No=0
1	Ear Discharge	Yes=1	No=0
1	Ear Drum Discoloration	No=1	Yes=0
1	Eye Ecchymosis	No=1	Yes=0
1	Breathing	1=Normal; 0=Irregular or Apnea	
1	Focal Weakness	Yes=1	No=0
1	Babinski	Yes=1	No=0
1	Other Reflex Abnormalities	Yes=1	No=0
1	Sensory Abnormality	Yes=1	No=0
1	Anisocoria	Yes=1	No=0
1	Other Cranial Nerve Abnormality	Yes=1	No=0
2	Evaluation of Injury	1=Trivial to 4=Severe	
3	Consciousness Scale	1=Normal to 5=Comatose	

OutcomesRun #1

Physician's Subjective Odds of a Skull Fracture, 4 Outcome Classes

Run #2

X-Ray Indicates Evidence of a Skull Fracture, 2 Outcome Classes

OUTCOMES

<u>Bits</u>	<u>Name</u>
4	Odds of a Skull Fracture or Mid-line Shift 1=Certain, 2=50:50, 3=1:10, 4=Remote
4	Reason for X-Ray 1=Suspicion of Skull Fracture or Mid-line Shift 2=Difficulty in Clinical Evaluation 3=Medical Legal Reasons 4=X-Ray Requested by Patient or Relative
3	Pineal Evaluation 1=Not Calcified 2=Normal Position 3=Significantly Shifted
2	X-Ray Provides Evidence of a Skull Fracture 1=Yes, No=0

Figure 12

CELL DEFINITION

PRIMARY ATTRIBUTES

EAR DISCHARGE	YES
EAR DRUM DISCOLORATION	YES

REDUNDANT ON REMAINING DATA

SENSORY ABNORMALITY	NO
---------------------	----

GRAPHICAL CELL DEFINITION SHOWING DOCTOR'S
SUBJECTIVE PROBABILITY VS. ATTRIBUTES
USING UNIFORM WEIGHTING

GRAPHICAL CELL DEFINITION SHOWING X-RAY
OUTCOME VS. ATTRIBUTES USING UNIFORM WEIGHTS

ATTRIBUTES AFFECTING THE PHYSICIAN'S
SUBJECTIVE PROBABILITY OF
FINDING A SKULL FRACTURE

Attributes Having a Significant Effect

- 1 Evaluation of Injury
- 2 Consciousness Scale
- 3 Sensory Abnormality
- 4 Breathing
- 5 Ear Discharge
- 6 Ear Drum Discoloration
- 7 Seizure
- 8 Palpable Bony Malalignment
- 9 Conscious/Unconscious
- 10 Hematoma
- 11 Anisocoria
- 12 Drowsiness
- 13 Eye Ecchymosis
- 14 Retrograde Amnesia
- 15 Vomiting
- 16 Headache
- 17 Swelling
- 18 Other Reflex Abnormality

Attributes Apparently Uncorrelated

- 1 Other Focal Sign
- 2 Nose Discharge
- 3 Focal Weakness
- 4 Other Cranial Nerve Abnormality
- 5 Babinski
- 6 Visual Disturbance

ATTRIBUTES AFFECTING THE PHYSICIAN'S
SUBJECTIVE PROBABILITY OF
FINDING A SKULL FRACTURE

Attributes Having a Significant Effect

- 1 Evaluation of Injury
- 2 Consciousness Scale
- 3 Sensory Abnormality
- 4 Breathing
- 5 Ear Discharge
- 6 Ear Drum Discoloration
- 7 Seizure
- 8 Palpable Bony Malalignment
- 9 Conscious/Unconscious
- 10 Hematoma
- 11 Anisocoria
- 12 Drowsiness
- 13 Eye Ecchymosis
- 14 Retrograde Amnesia
- 15 Vomiting
- 16 Headache
- 17 Swelling
- 18 Other Reflex Abnormality

Attributes Apparently Uncorrelated

- 1 Other Focal Sign
- 2 Nose Discharge
- 3 Focal Weakness
- 4 Other Cranial Nerve Abnormality
- 5 Babinski
- 6 Visual Disturbance

CORRELATION OF ATTRIBUTES
WITH X-RAY OUTCOME

Attributes Having a Significant Effect

- 1 Ear Discharge
- 2 Evaluation of Injury
- 3 Palpable Bony Malalignment
- 4 Consciousness Scale
- 5 Hematoma
- 6 Conscious/Unconscious
- 7 Seizure
- 8 Breathing
- 9 Drowsiness
- 10 Other Reflex Abnormality
- 11 Anisocoria
- 12 Headache
- 13 Nose Discharge
- 14 Other Focal Sign
- 15 Other Cranial Nerve Abnormality
- 16 Vomiting
- 17 Focal Weakness
- 18 Retrograde Amnesia

Attributes Apparently Uncorrelated

- 1 Sensory Abnormality
- 2 Eye Ecchymosis
- 3 Ear Drum Discoloration
- 4 Swelling
- 5 Babinski
- 6 Visual Disturbance

ATTRIBUTES AFFECTING PHYSICIAN'S SUBJECTIVE
PROBABILITY INCLUDING PHYSICIAN'S
ESTIMATE OF SEVERITY OF INJURY

Attributes Having a Significant Effect

- 1 Evaluation of Injury
- 2 Drowsiness
- 3 Conscious/Unconscious
- 4 Consciousness Scale
- 5 Breathing
- 6 Sensory Abnormality
- 7 Ear Discharge
- 8 Ear Drum Discoloration
- 9 Nose Discharge
- 10 Headache
- 11 Palpable Bony Malalignment
- 12 Swelling
- 13 Hematoma
- 14 Retrograde Amnesia

Attributes Apparently Uncorrelated

- 1 Vomiting
- 2 Seizure
- 3 Other Reflex Abnormalities
- 4 Anisocori

CORRELATION OF ATTRIBUTES WITH
X-RAY OUTCOMES INCLUDING PHYSICIAN'S
ESTIMATE OF SEVERITY OF INJURY

Attributes Having a Significant Effect

- 1 Evaluation of Injury
- 2 Consciousness Scale
- 3 Conscious/Unconscious
- 4 Sensory Abnormality
- 5 Ear Discharge
- 6 Other Reflex Abnormality
- 7 Palpable Bony Malalignment
- 8 Headache
- 9 Nose Discharge
- 10 Vomiting
- 11 Anisocori
- 12 Hematoma
- 13 Drowsiness
- 14 Retrograde Amnesia
- 15 Swelling

Attributes Apparently Uncorrelated

- 1 Seizure
- 2 Ear Drum Discoloration
- 3 Breathing

OUTCOMES

<u>Bits</u>	<u>Name</u>
4	Odds of a Skull Fracture or Mid-line Shift 1=Certain, 2=50:50, 3=1:10, 4=Remote
4	Reason for X-Ray 1=Suspicion of Skull Fracture or Mid-line Shift 2=Difficulty in Clinical Evaluation 3=Medical Legal Reasons 4=X-Ray Requested by Patient or Relative
3	Pineal Evaluation 1=Not Calcified 2=Normal Position 3=Significantly Shifted
2	X-Ray Provides Evidence of a Skull Fracture 1=Yes, No=0

APPROXIMATE CELL DEFINITION

Evaluation of Injury: Trivial
 Consciousness Scale : Normal
 Ear Discharge : No
 Breathing : Normal

Physician's Subjective Probability
 of a Skull Fracture

X-Ray Outcome

COMPARISON OF TWO CELLS WITH SIMILAR CELL DEFINITIONS
 IN WHICH THE PROBABILITY OF A FRACTURE IS SMALL

Physician's Subjective Probability
of a Skull Fracture

APPROXIMATE CELL DEFINITION

Palpable Bony Malalignment: Yes .9
Injury Scale : Serious

X-Ray Outcome

COMPARISON OF TWO CELL WITH SIMILAR CELL DEFINITIONS
IN WHICH THE PROBABILITY OF A FRACTURE IS LARGE

Figure 19

SHOWING THE DECREASE IN THE NUMBER OF EVENTS IN EACH STEP AS THE STEP NO. INCREASES. DATA FROM RUN NUMBER SIX

OUTCOME PROBABILITIES VS. STEP NUMBER FOR RUN NUMBER SIX SHOWING CONVERGENCE OF PROBABILITIES TO THE A PRIORI LEVEL

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