MONASH University

23 June 2011

CRC Mining Building 101
2436 Moggill Road
Pinjarra Hills
QLD 4069
Australia

Evaluation of the SmartCap technology – Letter of Assessment

Dear Sir / Madam,

Attached please find a report based on our initial analysis of data collected for analysis of the SmartCap fatigue monitoring technology.

The primary outcome used for this analysis was four consecutive misses during an Osler task, which is indicative of having brief periods of EEG defined sleep.

We found that the SmartCap fatigue algorithm performed well at identifying when people were severely sleepy in the laboratory setting.

- SmartCap fatigue level 4 provided a high sensitivity of 94.75%, correctly identifying most of the one minute periods when severe sleepiness was present;
- The lowest one-minute average output observed for an impaired (as per the definition for this primary analysis) subject was 3.683 (as determined by SmartCap).
- SmartCap average fatigue level 4 had a good specificity (0.82), hence it had a small to moderate false positive rate (meaning individuals who showed SmartCap fatigue level 4, but were not severely sleepy according to the primary outcome measure on the OSLER test).

Overall, the area under the curve of the ROC curves of 0.90 is consistent with the SmartCap fatigue algorithm being good at determining when severe sleepiness is present.

The laboratory environment is a controlled setting, where use of the SmartCap device was closely supervised by the investigators and the task used for the analysis minimises any movement that could impair the SmartCap signal quality. These limitations should be taken into account when considering potential use of the SmartCap device in a field setting.

Shantha M.W. Rajaratnam, PhD LLB
Associate Professor
Leader, Sleep and Chronobiology Group
Monash University

Mark E. Howard, *MBBS*, FRACP, GDEB, PhD
Director VRSS, Austin Health
Institute for Breathing & Sleep

Encl. Report 1 (4 June 2011)

School of Psychology and Psychiatry
Faculty of Medicine, Nursing and Health Sciences
Building 17, Monash University, Clayton Campus
Victoria 3800, Australia
Telephone +61 3 9905 3934 Facsimile +61 3 9905 3948
Shantha.Rajaratnam@med.monash.edu.au
www.monash.edu.au
ABN 12 377 614 012 CRICOS provider number 00008C

REPORT 1:

Evaluation of the SmartCap technology to monitor drowsiness in healthy volunteers exposed to sleep restriction – Relationship between the SmartCap fatigue algorithm and frequent misses on the Osler Test

4 June 2011

Study design summary

The study was conducted through collaboration between Monash University and Austin Health & Institute for Breathing and Sleep.

The project was conducted in accord with the study proposal and Human Research and Ethics application at Austin Health as a part of an ongoing research program. In total 21 healthy volunteers were recruited from a community sample and were screened to exclude medical conditions as per the study protocol. Participants undertook a performance battery in the sleep laboratory following a night of restricted sleep, with SmartCap recordings made during the tasks. This preliminary analysis pertains to SmartCap data recorded during the Osler task.

On the night prior to the laboratory visit, participants restricted their sleep to four hours time in bed, with bed time set at 02:00h and wake time at 06:00h, confirmed by a phone call to a message bank at bed- and wake-times, a sleep diary, and actigraphy. They presented to the laboratory at 09:00h to undertake the test battery, which included performing the 40 minute Osler task, the Psychomotor Vigilance Task, the Driving Simulation task and repeating the Osler.

Osler (Oxford Sleep Resistance Test): The Osler is a behavioural measure of sleep latency [1, 2], which is the current standard method for assessing fitness to drive. During the test, the participant is seated semi-reclined in a quiet, dark room and a light emitting diode positioned 4 feet away at eye level flashes regularly for 1 second every 3 seconds. The participant must respond to each signal using a hand held response pad. Sleep onset is defined when there is no response to seven consecutive flashes. This provides a high sensitivity and specificity compared to EEG defined sleep latency during the Maintenance of Wakefulness Test (MWT). Episodes of four or more consecutive missed signals on the Osler are highly predictive of "Microsleeps".

SmartCap recordings were made during all tasks. Scalp potential (effectively an equivalent of EEG, but not using ISO sensor locations) is measured at 1280Hz, and decimated to 256Hz, and can be transmitted if desired. Also included in this signal set is the common mode rejection signal, to indicate the effectiveness of the noise rejection part of the circuit. A fast fourier transform is calculated, and then manipulated to a power spectral density in 1Hz bands from 0-65Hz, which can also be transmitted.

Based on previously obtained training sets, *fatigue* was discretized into numerical equivalents from 1-5, with the following broad explanations associated:

Level 1 (Very alert)

Level 2 (Normal awake state) – this is the level that most people would experience during a reasonably active morning.

Level 3 (Mild drowsiness) – this is the "slightly tired" state one experiences in late afternoon, or after a big meal. It is not particularly unsafe to drive at level

3, however indicates slightly lowered vigilance, and slower reaction time. Symptoms are yawning and slightly slowed blinking.

Level 4 (Very drowsy) – this is the state when one would acknowledge they are in need of sleep symptoms include very slow reaction time, slow blink speed, regular yawning, micro sleeps and/or slumped posture

Level 5 (Clinically asleep) – as the name suggests, a person at level 5 is asleep, and not interacting with their surroundings.

Two revisions of the SmartCap fatigue analysis program used for this study were undertaken prior to this final analysis of the relationship between the SmartCap fatigue algorithm and the Osler data. These were undertaken following identical analysis to that presented here. Each analysis was undertaken by the investigators from Monash University and Austin Health & Institute for Breathing and Sleep. The adjustments to the analysis program were undertaken by CRC Mining without reference to the Osler data that was used for this final analysis.

Analysis

From the two Osler recordings in each of the 21 participants, in total 23 recordings of SmartCap data were available for analysis. 12 of the Osler recordings were used by CRC Mining for "training" of the SmartCap fatigue output (additional description from CRC Mining is appended below) and 11 were therefore available for comparison against the Osler data. We note that after initial analysis of these data, and visual inspection of SmartCap fatigue scores against Osler data by CRC Mining, CRC Mining corrected an error in the algorithm and provided the new data set to the researchers for analysis (although CRC Mining have confirmed that these Osler data were not used in the development of the revised fatigue algorithm). The Osler sessions were divided into one minute blocks for the analysis. We dichotomised each one minute block according to whether or not participants showed a high sleepiness level as indicated by four consecutive missed signals during that minute. This is strongly predictive of episodes of sleep of 3 sec duration (EEG theta activity, 4-7 Hz), sometimes referred to as "microsleeps" and hence this was used as the primary outcome variable. A secondary analysis was also performed for one minute blocks that contained four or more missed signals on the Osler in total for that minute, including non-consecutive misses, which is also indicative of a severe level of drowsiness. SmartCap data were analysed as directed by CRC Mining, with the average SmartCap fatigue level calculated for each minute. According to CRC Mining, the analysis program assesses whether excessive artefact (saturation of the signal) is present. Participants were not included if they had a saturated signal for most of their test session, however all data were included for the remaining participants (indicated by "saturated data not deleted"). The analysis was repeated after removing any minutes where the program assessed the SmartCap data as containing excessive artefact (indicated by "saturated data deleted"). Analysis of sensitivity and specificity and ROC curves were undertaken to determine the accuracy with which the SmartCap mean minutely fatigue level was associated with instances of excessive sleepiness or drowsiness on the Osler, within the one minute blocks.

Results

Data are presented in Appendix 1. This includes the ROC curves and data sheets for sensitivity and specificity of the one-minute average SmartCap fatigue level. In regards to the primary outcome measure of detecting four or more **consecutive** misses on the Osler in a minute: for the “saturated data not removed” analysis an average SmartCap fatigue level of 3 during the minute provided a sensitivity and specificity of 100% and 27.7% respectively and an average value of 4 provided a sensitivity and specificity of 94.7% and 81.9%, with an area under the curve for the ROC curve of 0.89; for the “saturated data removed” analysis an average SmartCap fatigue level of 3 provided a sensitivity and specificity of 100% and 29.5% respectively and an average value of 4 provided a sensitivity and specificity of 94.7% and 82.1%, with an area under the curve for the ROC curve of 0.90.

In regards to the secondary outcome measure of detecting four or more misses on the Osler in a minute **including non-consecutive misses**: for the “saturated data not removed” analysis an average SmartCap fatigue level of 3 during a one minute period provided a sensitivity and specificity of 98.6% and 33.7% respectively and an average value of 4 provided a sensitivity and specificity of 68.5% and 90.5% with an area under the curve for the ROC curve of 0.87; for the “saturated data removed” analysis an average SmartCap fatigue level of 3 during a one minute period provided a sensitivity and specificity of 98.6% and 35.9% respectively and an average value of 4 provided a sensitivity and specificity of 65.8% and 90.9% for detecting four or more misses on the Osler in a minute, with an area under the curve for the ROC curve of 0.86.

Conclusions

This project demonstrated that the SmartCap fatigue algorithm performed well at identifying when people were severely sleepy in the laboratory setting. The primary outcome used for this project was four consecutive misses during the Osler task, which is indicative of having brief periods of EEG defined sleep [3]. The SmartCap fatigue algorithm output was calculated and averaged for each minute and its ability to identify minutes when four consecutive misses had occurred was assessed using receiver operator characteristic (ROC) curve analysis. This analysis assesses the capability of a measure for discriminating between two different outcomes; in this case, the capability of SmartCap fatigue algorithm distinguishing between one minute periods with and without severe sleepiness. The area under the curve of the ROC curves of 0.89 to 0.90 are consistent with the SmartCap fatigue algorithm being good at determining when severe sleepiness is present in the laboratory. An average score of 4 provided a high sensitivity (94.75%), correctly identifying most of the one minute periods when severe sleepiness was present. It had a good specificity at an average score of four (81.9 to 82.1%). Hence, it had a small to moderate false positive rate at a one-minute average of four. The SmartCap fatigue algorithm also performed well in the secondary analysis (identifying minutes when four or more misses were present during any minute, not necessarily consecutive). The area under the Curve for the ROC curve was 0.86 to 0.87 for this analysis.

The laboratory environment is a controlled setting, where use of the SmartCap device was closely supervised by the investigators and the task used for the analysis minimises any movement that could impair the SmartCap signal quality. Participants with a high proportion of poor SmartCap signal were excluded from the analysis. These limitations should be taken into account when considering potential use of the

SmartCap device and fatigue algorithm in the field setting. Based on the results we report, we suggest that the SmartCap devise should be tested in the field setting.

Description of the fatigue algorithm

Introduction

The core component of the fatigue algorithm is a series of two artificial neural networks that are trained to 'learn' relationships between the frequency content of an individual's EEG and a measure of their drowsiness. This learning is achieved by presenting the networks with large numbers of examples of each drowsiness state, and the corresponding EEG frequency spectrum for numerous participants, and applying mathematical techniques to optimally capture this relationship in a highly non-linear, multidimensional set of equations.

There are a number of techniques we have applied during the training and confirmation process to ensure that these equations cater for as much person-to-person variability as possible. Our experience is that the more data from a wider range of participants is used, the more universal the result.

The following sections explain the details of the steps involved in calculating fatigue once the network equations have been 'trained'.

In total, **21%** of the data from the 11 participants provided (AB1, AB2, AD2, BC1, BC2, JB1, LS1, LS2, RC2, RJ1, RJ2) was used in the training process. Participant KM2 was excluded due to excessive saturation. **The remaining 79% of data was 'unseen' to the network equations**, and allowed us to assess the performance after the training process was complete.

Signal Measurement and Sampling

The sensors in the cap incorporate electronics that apply filtering (low pass) of the signals, so that any signals above 40Hz are significantly diminished. When converted to digital values in the processing card under the brim, we sample at 1280Hz, and then convert this to 256Hz – this allows us to ensure that there is no "aliasing" of high frequency noise in the frequency range of interest.

Once we have the 256Hz signals, we calculate the frequency spectrum of the signal over a **5-second window**, which is recalculated each second. The frequency spectrum calculated is from 0-64Hz.

Input Data Structure & Scaling

Using the entire frequency spectrum is a plausible approach, however if certain frequencies do not provide information related to an individual's drowsiness, results would have significant variability. Also, the input data must be scaled in a way to effectively make it non-dimensional, to allow person-to-person variations in signal strength and frequency content.

After hundreds of combinations of input structure and scaling were applied, we found the most suitable to be **an input of 1 to 13Hz, in 1Hz increments, scaled by the total signal power in the range of 13-30Hz**. This was not by design, but by an extensive trial and error process.

Coincidentally, this result is an input the captures **delta, theta and alpha waves**, presented in a finer resolution, and **scaled by the power of the beta waves**. This could be interpreted as effectively a ratio of an individual's drowsiness and wakefulness.

Neural Network Training & Structure

Two neural network equations are used, and represent a decision tree. Using drowsiness classifications of 2, 3 and 4 (alert, mild drowsiness and significant drowsiness (including sleep) respectively), the first network makes the decision "alert OR not alert".

The second network is employed if the decision is "not alert". This second network makes the decision "mild drowsiness OR significant drowsiness".

Moving window "winner" selection

The decision tree outcome results in an 'instantaneous' assessment of a person's drowsiness based on a 5-second window of EEG data, and this is reassessed each second. The result is

a stream of values each second, which may include other values that indicate that the signal was saturated.
A window of 12-seconds of these values is gathered, from which a ‘winner’ is selected. The winner is typically the most frequent drowsiness measure within the window, however strict criteria are applied to confirm that this is plausible based on other measures in the 12-second window. Some of these criteria are as follows:

- If each drowsiness measure appears 3 or more times within a window, no winner is selected. The result for this window is “fatigue unknown”
- If level 2 and level 4 are both present three or more times in a window, no winner is selected. The result for this window is “fatigue unknown”
- The winner must be present a minimum of seven times within a window if no other levels are present more than 3 times, or a minimum of five times if a ‘neighbouring’ level is present more than three times.
- If there is a tie and the levels are adjacent (e.g. 2/3 or 3/4), then a tie is declared, and the result for the window is the average of the two levels.

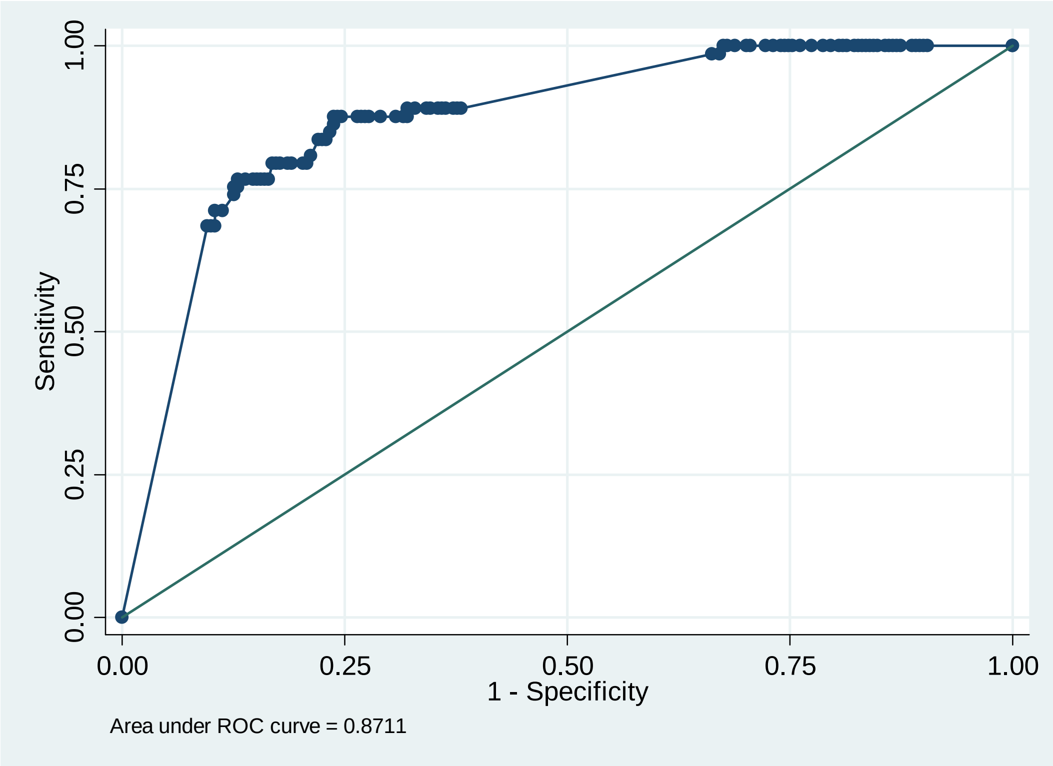
The window result is recalculated each second, applying these criteria. The result is known as the ‘**instantaneous measure of drowsiness**’.

Confirmation

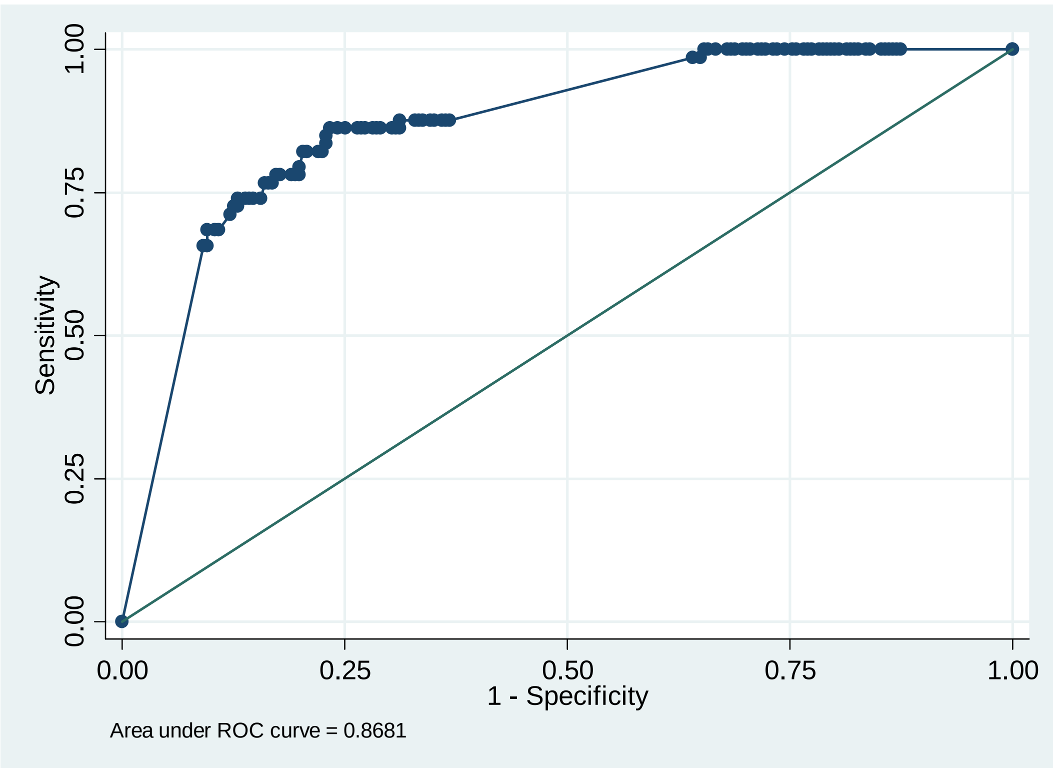
As a further step to avoid errors, a drowsiness measure is only reported if the same measure is calculated from seven consecutive windows. This reported measure is known as the ‘**confirmed fatigue result**’.
If no confirmed fatigue result is achieved within 60 seconds, the reported output is “fatigue unknown”.

SmartCap ROC Curves 16/05/2011

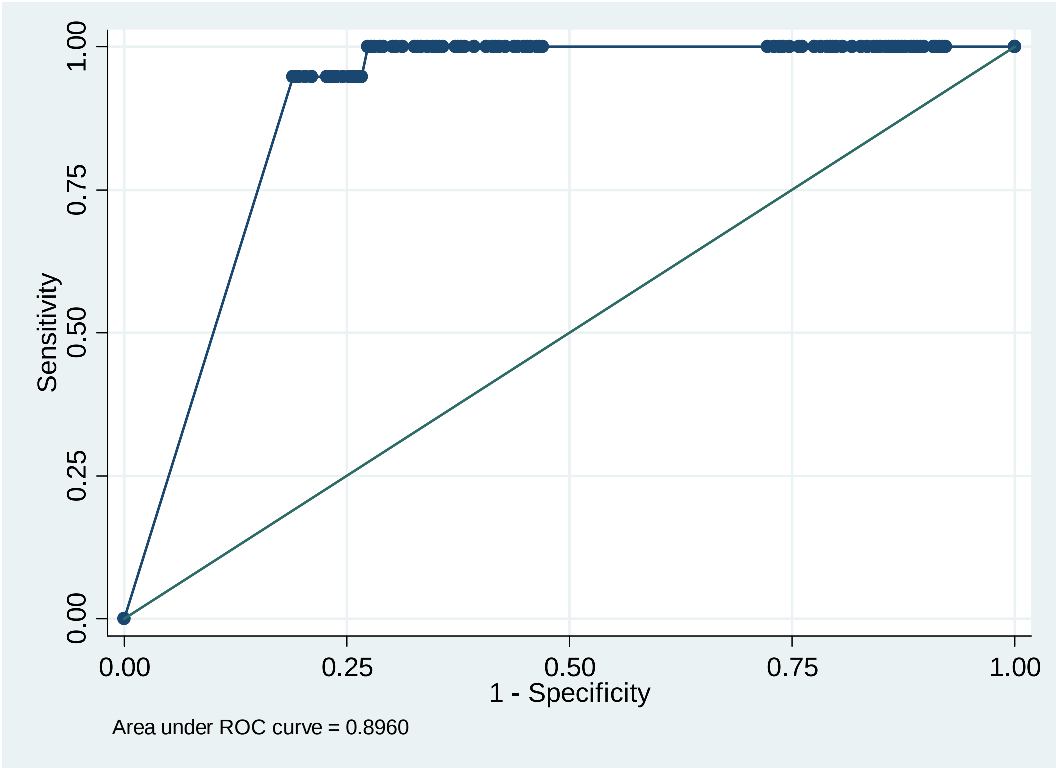
Overall OSLER misses (*saturated data not deleted*)



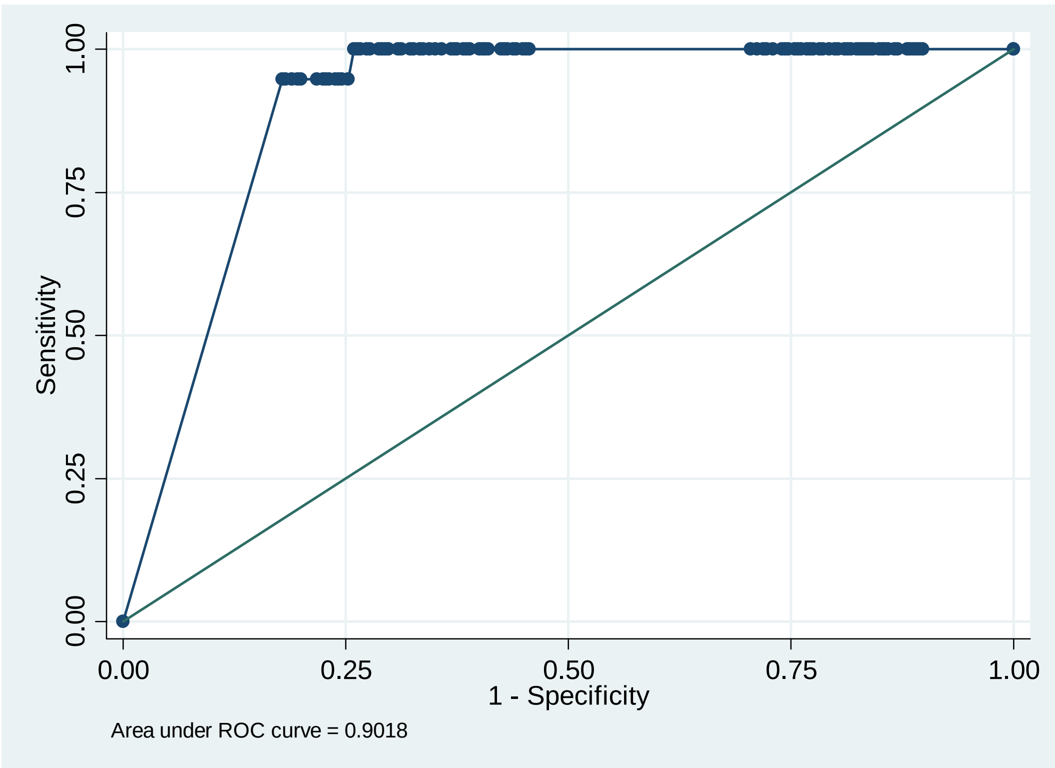
Overall OSLER misses (*saturated data deleted*)



Four consecutive misses (*saturated data not deleted*)



Four consecutive misses (*saturated data deleted*)



STATA sensitivity and specificity output 16/05/2011

Overall OSLER misses (*saturated data not deleted*)

```
. roctab   overallrecode sc_av,detail graph
```

Detailed report of Sensitivity and Specificity

Cutpoint	Sensitivity	Specificity	Correctly Classified	LR+	LR-
(>= 2)	100.00%	0.00%	24.01%	1.0000	
(>= 2.066667)	100.00%	9.52%	31.25%	1.1053	0.0000
(>= 2.133333)	100.00%	9.96%	31.58%	1.1106	0.0000
(>= 2.166667)	100.00%	10.39%	31.91%	1.1159	0.0000
(>= 2.183333)	100.00%	10.82%	32.24%	1.1214	0.0000
(>= 2.2)	100.00%	11.26%	32.57%	1.1268	0.0000
(>= 2.266667)	100.00%	12.55%	33.55%	1.1436	0.0000
(>= 2.283333)	100.00%	12.99%	33.88%	1.1493	0.0000
(>= 2.316667)	100.00%	13.42%	34.21%	1.1550	0.0000
(>= 2.333333)	100.00%	13.85%	34.54%	1.1608	0.0000
(>= 2.366667)	100.00%	14.29%	34.87%	1.1667	0.0000
(>= 2.383333)	100.00%	15.15%	35.53%	1.1786	0.0000
(>= 2.416667)	100.00%	15.58%	35.86%	1.1846	0.0000
(>= 2.433333)	100.00%	16.02%	36.18%	1.1907	0.0000
(>= 2.45)	100.00%	16.45%	36.51%	1.1969	0.0000
(>= 2.483333)	100.00%	16.88%	36.84%	1.2031	0.0000
(>= 2.516667)	100.00%	17.32%	37.17%	1.2094	0.0000
(>= 2.541667)	100.00%	17.75%	37.50%	1.2158	0.0000
(>= 2.55)	100.00%	18.61%	38.16%	1.2287	0.0000
(>= 2.583333)	100.00%	19.05%	38.49%	1.2353	0.0000
(>= 2.6)	100.00%	19.48%	38.82%	1.2419	0.0000
(>= 2.616667)	100.00%	20.35%	39.47%	1.2554	0.0000
(>= 2.683333)	100.00%	21.21%	40.13%	1.2692	0.0000
(>= 2.733333)	100.00%	22.51%	41.12%	1.2905	0.0000
(>= 2.75)	100.00%	23.81%	42.11%	1.3125	0.0000
(>= 2.766667)	100.00%	24.68%	42.76%	1.3276	0.0000
(>= 2.783333)	100.00%	25.11%	43.09%	1.3353	0.0000
(>= 2.8)	100.00%	25.54%	43.42%	1.3430	0.0000
(>= 2.816667)	100.00%	25.97%	43.75%	1.3509	0.0000
(>= 2.833333)	100.00%	26.84%	44.41%	1.3669	0.0000
(>= 2.85)	100.00%	27.71%	45.07%	1.3832	0.0000
(>= 2.866667)	100.00%	29.44%	46.38%	1.4172	0.0000
(>= 2.883333)	100.00%	29.87%	46.71%	1.4259	0.0000
(>= 2.9)	100.00%	31.17%	47.70%	1.4528	0.0000
(>= 2.916667)	100.00%	32.03%	48.36%	1.4713	0.0000
(>= 2.933333)	100.00%	32.47%	48.68%	1.4808	0.0000
(>= 2.983333)	98.63%	32.90%	48.68%	1.4699	0.0416
(>= 3)	98.63%	33.77%	49.34%	1.4891	0.0406
(>= 3.016667)	89.04%	61.90%	68.42%	2.3373	0.1770
(>= 3.033333)	89.04%	62.34%	68.75%	2.3642	0.1758
(>= 3.058333)	89.04%	62.77%	69.08%	2.3917	0.1746
(>= 3.1)	89.04%	63.64%	69.74%	2.4486	0.1722
(>= 3.116667)	89.04%	64.07%	70.07%	2.4781	0.1710
(>= 3.133333)	89.04%	64.50%	70.39%	2.5084	0.1699
(>= 3.141667)	89.04%	65.37%	71.05%	2.5711	0.1676
(>= 3.15)	89.04%	65.80%	71.38%	2.6036	0.1665
(>= 3.166667)	89.04%	67.10%	72.37%	2.7064	0.1633
(>= 3.183333)	89.04%	67.97%	73.03%	2.7795	0.1612
(>= 3.2)	87.67%	67.97%	72.70%	2.7368	0.1814
(>= 3.216667)	87.67%	68.40%	73.03%	2.7743	0.1802
(>= 3.233333)	87.67%	69.26%	73.68%	2.8524	0.1780
(>= 3.266667)	87.67%	71.00%	75.00%	3.0227	0.1737
(>= 3.283333)	87.67%	72.29%	75.99%	3.1644	0.1705
(>= 3.333333)	87.67%	72.73%	76.32%	3.2146	0.1695
(>= 3.341667)	87.67%	73.16%	76.64%	3.2665	0.1685
(>= 3.366667)	87.67%	73.59%	76.97%	3.3200	0.1675
(>= 3.383333)	87.67%	75.32%	78.29%	3.5530	0.1637
(>= 3.4)	87.67%	75.76%	78.62%	3.6164	0.1627
(>= 3.416667)	87.67%	76.19%	78.95%	3.6822	0.1618

(>= 3.433333)	86.30%	76.19%	78.62%	3.6247	0.1798
(>= 3.45)	84.93%	76.62%	78.62%	3.6332	0.1967
(>= 3.466667)	83.56%	77.06%	78.62%	3.6420	0.2133
(>= 3.483333)	83.56%	77.49%	78.95%	3.7121	0.2121
(>= 3.5)	83.56%	77.92%	79.28%	3.7848	0.2110
(>= 3.516667)	80.82%	78.79%	79.28%	3.8102	0.2434
(>= 3.55)	79.45%	79.22%	79.28%	3.8236	0.2594
(>= 3.566667)	79.45%	79.65%	79.61%	3.9050	0.2580
(>= 3.583333)	79.45%	80.95%	80.59%	4.1712	0.2538
(>= 3.6)	79.45%	81.39%	80.92%	4.2682	0.2525
(>= 3.65)	79.45%	82.25%	81.58%	4.4764	0.2498
(>= 3.666667)	79.45%	82.68%	81.91%	4.5884	0.2485
(>= 3.683333)	79.45%	83.12%	82.24%	4.7060	0.2472
(>= 3.7)	76.71%	83.55%	81.91%	4.6633	0.2787
(>= 3.708333)	76.71%	83.98%	82.24%	4.7893	0.2773
(>= 3.733333)	76.71%	84.42%	82.57%	4.9224	0.2759
(>= 3.75)	76.71%	84.85%	82.89%	5.0630	0.2745
(>= 3.766667)	76.71%	85.28%	83.22%	5.2119	0.2731
(>= 3.783333)	76.71%	86.15%	83.88%	5.5377	0.2703
(>= 3.8)	76.71%	87.01%	84.54%	5.9068	0.2676
(>= 3.816667)	75.34%	87.01%	84.21%	5.8014	0.2834
(>= 3.833333)	75.34%	87.45%	84.54%	6.0014	0.2820
(>= 3.85)	73.97%	87.45%	84.21%	5.8923	0.2976
(>= 3.941667)	71.23%	88.74%	84.54%	6.3288	0.3242
(>= 3.95)	71.23%	89.61%	85.20%	6.8562	0.3210
(>= 3.966667)	68.49%	89.61%	84.54%	6.5925	0.3516
(>= 3.983333)	68.49%	90.04%	84.87%	6.8791	0.3499
(>= 4)	68.49%	90.48%	85.20%	7.1918	0.3482
(> 4)	0.00%	100.00%	75.99%		1.0000

Obs	ROC Area	Std. Err.	-Asymptotic Normal-- [95% Conf.	Interval]
304	0.8711	0.0223	0.82749	0.91473

Overall OSLER misses (*saturated data deleted*)

```
. roctab overallrecode  sc_av_sat,detail graph
```

Detailed report of Sensitivity and Specificity

Cutpoint	Sensitivity	Specificity	Correctly Classified	LR+	LR-
(>= 2)	100.00%	0.00%	24.01%	1.0000	
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(>= 2.116667)	100.00%	12.99%	33.88%	1.1493	0.0000
(>= 2.137931)	100.00%	13.42%	34.21%	1.1550	0.0000
(>= 2.166667)	100.00%	13.85%	34.54%	1.1608	0.0000
(>= 2.183333)	100.00%	14.29%	34.87%	1.1667	0.0000
(>= 2.2)	100.00%	14.72%	35.20%	1.1726	0.0000
(>= 2.208333)	100.00%	16.02%	36.18%	1.1907	0.0000
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(>= 2.316667)	100.00%	17.75%	37.50%	1.2158	0.0000
(>= 2.333333)	100.00%	18.18%	37.83%	1.2222	0.0000
(>= 2.366667)	100.00%	18.61%	38.16%	1.2287	0.0000
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(>= 2.583333)	100.00%	22.94%	41.45%	1.2978	0.0000
(>= 2.6)	100.00%	23.38%	41.78%	1.3051	0.0000
(>= 2.616667)	100.00%	24.24%	42.43%	1.3200	0.0000
(>= 2.683333)	100.00%	24.68%	42.76%	1.3276	0.0000
(>= 2.733333)	100.00%	25.54%	43.42%	1.3430	0.0000
(>= 2.75)	100.00%	26.41%	44.08%	1.3588	0.0000
(>= 2.766667)	100.00%	26.84%	44.41%	1.3669	0.0000
(>= 2.783333)	100.00%	27.71%	45.07%	1.3832	0.0000
(>= 2.8)	100.00%	28.14%	45.39%	1.3916	0.0000
(>= 2.816667)	100.00%	28.57%	45.72%	1.4000	0.0000
(>= 2.818182)	100.00%	29.44%	46.38%	1.4172	0.0000
(>= 2.830189)	100.00%	29.87%	46.71%	1.4259	0.0000
(>= 2.833333)	100.00%	30.30%	47.04%	1.4348	0.0000
(>= 2.85)	100.00%	31.17%	47.70%	1.4528	0.0000
(>= 2.866667)	100.00%	31.60%	48.03%	1.4620	0.0000
(>= 2.883333)	100.00%	32.03%	48.36%	1.4713	0.0000
(>= 2.9)	100.00%	33.33%	49.34%	1.5000	0.0000
(>= 2.916667)	100.00%	34.20%	50.00%	1.5197	0.0000
(>= 2.933333)	100.00%	34.63%	50.33%	1.5298	0.0000
(>= 2.983333)	98.63%	35.06%	50.33%	1.5189	0.0391
(>= 3)	98.63%	35.93%	50.99%	1.5394	0.0381
(>= 3.016667)	87.67%	63.20%	69.08%	2.3826	0.1951
(>= 3.033333)	87.67%	63.64%	69.41%	2.4110	0.1937
(>= 3.058333)	87.67%	64.07%	69.74%	2.4400	0.1924
(>= 3.116667)	87.67%	64.94%	70.39%	2.5003	0.1899
(>= 3.133333)	87.67%	65.37%	70.72%	2.5315	0.1886
(>= 3.141667)	87.67%	66.23%	71.38%	2.5964	0.1861
(>= 3.15)	87.67%	66.67%	71.71%	2.6301	0.1849
(>= 3.166667)	87.67%	67.10%	72.04%	2.6647	0.1837
(>= 3.183333)	87.67%	68.83%	73.36%	2.8128	0.1791
(>= 3.2)	86.30%	68.83%	73.03%	2.7688	0.1990
(>= 3.216667)	86.30%	69.26%	73.36%	2.8078	0.1978
(>= 3.233333)	86.30%	69.70%	73.68%	2.8479	0.1965
(>= 3.240741)	86.30%	71.00%	74.67%	2.9755	0.1930
(>= 3.25)	86.30%	71.43%	75.00%	3.0205	0.1918
(>= 3.266667)	86.30%	71.86%	75.33%	3.0670	0.1906
(>= 3.268518)	86.30%	72.73%	75.99%	3.1644	0.1884
(>= 3.333333)	86.30%	73.16%	76.32%	3.2154	0.1872
(>= 3.366667)	86.30%	73.59%	76.64%	3.2681	0.1861
(>= 3.383333)	86.30%	74.89%	77.63%	3.4372	0.1829
(>= 3.4)	86.30%	75.76%	78.29%	3.5599	0.1808
(>= 3.416667)	86.30%	76.62%	78.95%	3.6918	0.1788

(>= 3.433333)	84.93%	77.06%	78.95%	3.7017	0.1956
(>= 3.45)	83.56%	77.06%	78.62%	3.6420	0.2133
(>= 3.454545)	82.19%	77.49%	78.62%	3.6512	0.2298
(>= 3.466667)	82.19%	77.92%	78.95%	3.7228	0.2285
(>= 3.483333)	82.19%	79.22%	79.93%	3.9555	0.2248
(>= 3.5)	82.19%	79.65%	80.26%	4.0396	0.2236
(>= 3.516667)	79.45%	80.09%	79.93%	3.9899	0.2566
(>= 3.533333)	78.08%	80.09%	79.61%	3.9211	0.2737
(>= 3.553191)	78.08%	80.52%	79.93%	4.0082	0.2722
(>= 3.566667)	78.08%	80.95%	80.26%	4.0993	0.2707
(>= 3.583333)	78.08%	82.25%	81.25%	4.3993	0.2665
(>= 3.6)	78.08%	82.68%	81.58%	4.5092	0.2651
(>= 3.666667)	76.71%	83.12%	81.58%	4.5437	0.2802
(>= 3.680851)	76.71%	83.55%	81.91%	4.6633	0.2787
(>= 3.683333)	76.71%	83.98%	82.24%	4.7893	0.2773
(>= 3.7)	73.97%	84.42%	81.91%	4.7466	0.3083
(>= 3.708333)	73.97%	85.28%	82.57%	5.0258	0.3052
(>= 3.766667)	73.97%	85.71%	82.89%	5.1781	0.3037
(>= 3.783333)	73.97%	86.15%	83.22%	5.3399	0.3021
(>= 3.8)	73.97%	87.01%	83.88%	5.6959	0.2991
(>= 3.816667)	72.60%	87.01%	83.55%	5.5904	0.3149
(>= 3.833333)	72.60%	87.45%	83.88%	5.7832	0.3133
(>= 3.85)	71.23%	87.88%	83.88%	5.8767	0.3274
(>= 3.916667)	68.49%	89.18%	84.21%	6.3288	0.3533
(>= 3.941667)	68.49%	89.61%	84.54%	6.5925	0.3516
(>= 3.95)	68.49%	90.48%	85.20%	7.1918	0.3482
(>= 3.983333)	65.75%	90.48%	84.54%	6.9041	0.3785
(>= 4)	65.75%	90.91%	84.87%	7.2329	0.3767
(> 4)	0.00%	100.00%	75.99%		1.0000

Obs	ROC Area	Std. Err.	-Asymptotic Normal-- [95% Conf.	Interval]
304	0.8681	0.0224	0.82417	0.91200

Four consecutive misses (*saturated data not deleted*)

```
. roctab consrecode sc_av,detail graph
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Detailed report of Sensitivity and Specificity

Cutpoint	Sensitivity	Specificity	Correctly Classified	LR+	LR-
(>= 2)	100.00%	0.00%	6.25%	1.0000	
(>= 2.066667)	100.00%	7.72%	13.49%	1.0837	0.0000
(>= 2.133333)	100.00%	8.07%	13.82%	1.0878	0.0000
(>= 2.166667)	100.00%	8.42%	14.14%	1.0920	0.0000
(>= 2.183333)	100.00%	8.77%	14.47%	1.0962	0.0000
(>= 2.2)	100.00%	9.12%	14.80%	1.1004	0.0000
(>= 2.266667)	100.00%	10.18%	15.79%	1.1133	0.0000
(>= 2.283333)	100.00%	10.53%	16.12%	1.1176	0.0000
(>= 2.316667)	100.00%	10.88%	16.45%	1.1220	0.0000
(>= 2.333333)	100.00%	11.23%	16.78%	1.1265	0.0000
(>= 2.366667)	100.00%	11.58%	17.11%	1.1310	0.0000
(>= 2.383333)	100.00%	12.28%	17.76%	1.1400	0.0000
(>= 2.416667)	100.00%	12.63%	18.09%	1.1446	0.0000
(>= 2.433333)	100.00%	12.98%	18.42%	1.1492	0.0000
(>= 2.45)	100.00%	13.33%	18.75%	1.1538	0.0000
(>= 2.483333)	100.00%	13.68%	19.08%	1.1585	0.0000
(>= 2.516667)	100.00%	14.04%	19.41%	1.1633	0.0000
(>= 2.541667)	100.00%	14.39%	19.74%	1.1680	0.0000
(>= 2.55)	100.00%	15.09%	20.39%	1.1777	0.0000
(>= 2.583333)	100.00%	15.44%	20.72%	1.1826	0.0000
(>= 2.6)	100.00%	15.79%	21.05%	1.1875	0.0000
(>= 2.616667)	100.00%	16.49%	21.71%	1.1975	0.0000
(>= 2.683333)	100.00%	17.19%	22.37%	1.2076	0.0000
(>= 2.733333)	100.00%	18.25%	23.36%	1.2232	0.0000
(>= 2.75)	100.00%	19.30%	24.34%	1.2391	0.0000
(>= 2.766667)	100.00%	20.00%	25.00%	1.2500	0.0000
(>= 2.783333)	100.00%	20.35%	25.33%	1.2555	0.0000
(>= 2.8)	100.00%	20.70%	25.66%	1.2611	0.0000
(>= 2.816667)	100.00%	21.05%	25.99%	1.2667	0.0000
(>= 2.833333)	100.00%	21.75%	26.64%	1.2780	0.0000
(>= 2.85)	100.00%	22.46%	27.30%	1.2896	0.0000
(>= 2.866667)	100.00%	23.86%	28.62%	1.3134	0.0000
(>= 2.883333)	100.00%	24.21%	28.95%	1.3194	0.0000
(>= 2.9)	100.00%	25.26%	29.93%	1.3380	0.0000
(>= 2.916667)	100.00%	25.96%	30.59%	1.3507	0.0000
(>= 2.933333)	100.00%	26.32%	30.92%	1.3571	0.0000
(>= 2.983333)	100.00%	27.02%	31.58%	1.3702	0.0000
(>= 3)	100.00%	27.72%	32.24%	1.3835	0.0000
(>= 3.016667)	100.00%	52.98%	55.92%	2.1269	0.0000
(>= 3.033333)	100.00%	53.33%	56.25%	2.1429	0.0000
(>= 3.058333)	100.00%	53.68%	56.58%	2.1591	0.0000
(>= 3.1)	100.00%	54.39%	57.24%	2.1923	0.0000
(>= 3.116667)	100.00%	54.74%	57.57%	2.2093	0.0000
(>= 3.133333)	100.00%	55.09%	57.89%	2.2266	0.0000
(>= 3.141667)	100.00%	55.79%	58.55%	2.2619	0.0000
(>= 3.15)	100.00%	56.14%	58.88%	2.2800	0.0000
(>= 3.166667)	100.00%	57.19%	59.87%	2.3361	0.0000
(>= 3.183333)	100.00%	57.89%	60.53%	2.3750	0.0000
(>= 3.2)	100.00%	58.25%	60.86%	2.3950	0.0000
(>= 3.216667)	100.00%	58.60%	61.18%	2.4153	0.0000
(>= 3.233333)	100.00%	59.30%	61.84%	2.4569	0.0000
(>= 3.266667)	100.00%	60.70%	63.16%	2.5446	0.0000
(>= 3.283333)	100.00%	61.75%	64.14%	2.6147	0.0000
(>= 3.333333)	100.00%	62.11%	64.47%	2.6389	0.0000
(>= 3.341667)	100.00%	62.46%	64.80%	2.6636	0.0000
(>= 3.366667)	100.00%	62.81%	65.13%	2.6887	0.0000
(>= 3.383333)	100.00%	64.21%	66.45%	2.7941	0.0000
(>= 3.4)	100.00%	64.56%	66.78%	2.8218	0.0000
(>= 3.416667)	100.00%	64.91%	67.11%	2.8500	0.0000
(>= 3.433333)	100.00%	65.26%	67.43%	2.8788	0.0000
(>= 3.45)	100.00%	65.96%	68.09%	2.9381	0.0000
(>= 3.466667)	100.00%	66.67%	68.75%	3.0000	0.0000

(>= 3.483333)	100.00%	67.02%	69.08%	3.0319	0.0000
(>= 3.5)	100.00%	67.37%	69.41%	3.0645	0.0000
(>= 3.516667)	100.00%	68.77%	70.72%	3.2022	0.0000
(>= 3.55)	100.00%	69.47%	71.38%	3.2759	0.0000
(>= 3.566667)	100.00%	69.82%	71.71%	3.3140	0.0000
(>= 3.583333)	100.00%	70.88%	72.70%	3.4337	0.0000
(>= 3.6)	100.00%	71.23%	73.03%	3.4756	0.0000
(>= 3.65)	100.00%	71.93%	73.68%	3.5625	0.0000
(>= 3.666667)	100.00%	72.28%	74.01%	3.6076	0.0000
(>= 3.683333)	100.00%	72.63%	74.34%	3.6538	0.0000
(>= 3.7)	94.74%	73.33%	74.67%	3.5526	0.0718
(>= 3.708333)	94.74%	73.68%	75.00%	3.6000	0.0714
(>= 3.733333)	94.74%	74.04%	75.33%	3.6486	0.0711
(>= 3.75)	94.74%	74.39%	75.66%	3.6986	0.0708
(>= 3.766667)	94.74%	74.74%	75.99%	3.7500	0.0704
(>= 3.783333)	94.74%	75.44%	76.64%	3.8571	0.0698
(>= 3.8)	94.74%	76.14%	77.30%	3.9706	0.0691
(>= 3.816667)	94.74%	76.49%	77.63%	4.0299	0.0688
(>= 3.833333)	94.74%	76.84%	77.96%	4.0909	0.0685
(>= 3.85)	94.74%	77.19%	78.29%	4.1538	0.0682
(>= 3.941667)	94.74%	78.95%	79.93%	4.5000	0.0667
(>= 3.95)	94.74%	79.65%	80.59%	4.6552	0.0661
(>= 3.966667)	94.74%	80.35%	81.25%	4.8214	0.0655
(>= 3.983333)	94.74%	80.70%	81.58%	4.9091	0.0652
(>= 4)	94.74%	81.05%	81.91%	5.0000	0.0649
(> 4)	0.00%	100.00%	93.75%		1.0000

Obs	ROC Area	Std. Err.	-Asymptotic Normal-- [95% Conf.	Interval]
304	0.8960	0.0153	0.86613	0.92593

Four consecutive misses (*saturated data deleted*)

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. roctab consrecode  sc_av_sat,detail graph
```

Detailed report of Sensitivity and Specificity

Cutpoint	Sensitivity	Specificity	Correctly Classified	LR+	LR-
(>= 2)	100.00%	0.00%	6.25%	1.0000	
(>= 2.066667)	100.00%	10.18%	15.79%	1.1133	0.0000
(>= 2.116667)	100.00%	10.53%	16.12%	1.1176	0.0000
(>= 2.137931)	100.00%	10.88%	16.45%	1.1220	0.0000
(>= 2.166667)	100.00%	11.23%	16.78%	1.1265	0.0000
(>= 2.183333)	100.00%	11.58%	17.11%	1.1310	0.0000
(>= 2.2)	100.00%	11.93%	17.43%	1.1355	0.0000
(>= 2.208333)	100.00%	12.98%	18.42%	1.1492	0.0000
(>= 2.266667)	100.00%	13.33%	18.75%	1.1538	0.0000
(>= 2.283333)	100.00%	14.04%	19.41%	1.1633	0.0000
(>= 2.316667)	100.00%	14.39%	19.74%	1.1680	0.0000
(>= 2.333333)	100.00%	14.74%	20.07%	1.1728	0.0000
(>= 2.366667)	100.00%	15.09%	20.39%	1.1777	0.0000
(>= 2.383333)	100.00%	15.79%	21.05%	1.1875	0.0000
(>= 2.416667)	100.00%	16.14%	21.38%	1.1925	0.0000
(>= 2.433333)	100.00%	16.49%	21.71%	1.1975	0.0000
(>= 2.483333)	100.00%	16.84%	22.04%	1.2025	0.0000
(>= 2.516667)	100.00%	17.19%	22.37%	1.2076	0.0000
(>= 2.541667)	100.00%	17.54%	22.70%	1.2128	0.0000
(>= 2.55)	100.00%	18.25%	23.36%	1.2232	0.0000
(>= 2.583333)	100.00%	18.60%	23.68%	1.2284	0.0000
(>= 2.6)	100.00%	18.95%	24.01%	1.2338	0.0000
(>= 2.616667)	100.00%	19.65%	24.67%	1.2445	0.0000
(>= 2.683333)	100.00%	20.00%	25.00%	1.2500	0.0000
(>= 2.733333)	100.00%	20.70%	25.66%	1.2611	0.0000
(>= 2.75)	100.00%	21.40%	26.32%	1.2723	0.0000
(>= 2.766667)	100.00%	21.75%	26.64%	1.2780	0.0000
(>= 2.783333)	100.00%	22.46%	27.30%	1.2896	0.0000
(>= 2.8)	100.00%	22.81%	27.63%	1.2955	0.0000
(>= 2.816667)	100.00%	23.16%	27.96%	1.3014	0.0000
(>= 2.818182)	100.00%	23.86%	28.62%	1.3134	0.0000
(>= 2.830189)	100.00%	24.21%	28.95%	1.3194	0.0000
(>= 2.833333)	100.00%	24.56%	29.28%	1.3256	0.0000
(>= 2.85)	100.00%	25.26%	29.93%	1.3380	0.0000
(>= 2.866667)	100.00%	25.61%	30.26%	1.3443	0.0000
(>= 2.883333)	100.00%	25.96%	30.59%	1.3507	0.0000
(>= 2.9)	100.00%	27.02%	31.58%	1.3702	0.0000
(>= 2.916667)	100.00%	27.72%	32.24%	1.3835	0.0000
(>= 2.933333)	100.00%	28.07%	32.57%	1.3902	0.0000
(>= 2.983333)	100.00%	28.77%	33.22%	1.4039	0.0000
(>= 3)	100.00%	29.47%	33.88%	1.4179	0.0000
(>= 3.016667)	100.00%	54.39%	57.24%	2.1923	0.0000
(>= 3.033333)	100.00%	54.74%	57.57%	2.2093	0.0000
(>= 3.058333)	100.00%	55.09%	57.89%	2.2266	0.0000
(>= 3.116667)	100.00%	55.79%	58.55%	2.2619	0.0000
(>= 3.133333)	100.00%	56.14%	58.88%	2.2800	0.0000
(>= 3.141667)	100.00%	56.84%	59.54%	2.3171	0.0000
(>= 3.15)	100.00%	57.19%	59.87%	2.3361	0.0000
(>= 3.166667)	100.00%	57.54%	60.20%	2.3554	0.0000
(>= 3.183333)	100.00%	58.95%	61.51%	2.4359	0.0000
(>= 3.2)	100.00%	59.30%	61.84%	2.4569	0.0000
(>= 3.216667)	100.00%	59.65%	62.17%	2.4783	0.0000
(>= 3.233333)	100.00%	60.00%	62.50%	2.5000	0.0000
(>= 3.240741)	100.00%	61.05%	63.49%	2.5676	0.0000
(>= 3.25)	100.00%	61.40%	63.82%	2.5909	0.0000
(>= 3.266667)	100.00%	61.75%	64.14%	2.6147	0.0000
(>= 3.268518)	100.00%	62.46%	64.80%	2.6636	0.0000
(>= 3.333333)	100.00%	62.81%	65.13%	2.6887	0.0000
(>= 3.366667)	100.00%	63.16%	65.46%	2.7143	0.0000
(>= 3.383333)	100.00%	64.21%	66.45%	2.7941	0.0000
(>= 3.4)	100.00%	64.91%	67.11%	2.8500	0.0000
(>= 3.416667)	100.00%	65.61%	67.76%	2.9082	0.0000

(>= 3.433333)	100.00%	66.32%	68.42%	2.9687	0.0000
(>= 3.45)	100.00%	66.67%	68.75%	3.0000	0.0000
(>= 3.454545)	100.00%	67.37%	69.41%	3.0645	0.0000
(>= 3.466667)	100.00%	67.72%	69.74%	3.0978	0.0000
(>= 3.483333)	100.00%	68.77%	70.72%	3.2022	0.0000
(>= 3.5)	100.00%	69.12%	71.05%	3.2386	0.0000
(>= 3.516667)	100.00%	70.18%	72.04%	3.3529	0.0000
(>= 3.533333)	100.00%	70.53%	72.37%	3.3929	0.0000
(>= 3.553191)	100.00%	70.88%	72.70%	3.4337	0.0000
(>= 3.566667)	100.00%	71.23%	73.03%	3.4756	0.0000
(>= 3.583333)	100.00%	72.28%	74.01%	3.6076	0.0000
(>= 3.6)	100.00%	72.63%	74.34%	3.6538	0.0000
(>= 3.666667)	100.00%	73.33%	75.00%	3.7500	0.0000
(>= 3.680851)	100.00%	73.68%	75.33%	3.8000	0.0000
(>= 3.683333)	100.00%	74.04%	75.66%	3.8514	0.0000
(>= 3.7)	94.74%	74.74%	75.99%	3.7500	0.0704
(>= 3.708333)	94.74%	75.44%	76.64%	3.8571	0.0698
(>= 3.766667)	94.74%	75.79%	76.97%	3.9130	0.0694
(>= 3.783333)	94.74%	76.14%	77.30%	3.9706	0.0691
(>= 3.8)	94.74%	76.84%	77.96%	4.0909	0.0685
(>= 3.816667)	94.74%	77.19%	78.29%	4.1538	0.0682
(>= 3.833333)	94.74%	77.54%	78.62%	4.2188	0.0679
(>= 3.85)	94.74%	78.25%	79.28%	4.3548	0.0673
(>= 3.916667)	94.74%	80.00%	80.92%	4.7368	0.0658
(>= 3.941667)	94.74%	80.35%	81.25%	4.8214	0.0655
(>= 3.95)	94.74%	81.05%	81.91%	5.0000	0.0649
(>= 3.983333)	94.74%	81.75%	82.57%	5.1923	0.0644
(>= 4)	94.74%	82.11%	82.89%	5.2941	0.0641
(> 4)	0.00%	100.00%	93.75%		1.0000

Obs	ROC Area	Std. Err.	-Asymptotic Normal-- [95% Conf.	Interval]
304	0.9018	0.0148	0.87280	0.93071

References

1.Mazza, S., et al., *Analysis of error profiles occurring during the OSLER test: a sensitive mean of detecting fluctuations in vigilance in patients with obstructive sleep apnea syndrome.* Am J Respir Crit Care Med, 2002. **166**(4): p. 474-8.

2.Priest, B., et al., *Microsleep during a simplified maintenance of wakefulness test. A validation study of the OSLER test.* Am J Respir Crit Care Med, 2001. **163**(7): p. 1619-25.

3.Priest, B., et al., *Microsleep during a simplified maintenance of wakefulness test. A validation study of the OSLER test.* American Journal of Respiratory & Critical Care Medicine, 2001. **163**(7): p. 1619-25.