Diagnostic Accuracy of the Berlin Questionnaire in Detecting Sleep-Disordered Breathing in Patients With a Recent Myocardial Infarction

Fatima H. Sert Kuniyoshi, PhD; Mark R. Zellmer, PhD; Andrew D. Calvin, MD, MPH; Francisco Lopez-Jimenez, MD; Felipe N. Albuquerque, MD; Christelle van der Walt, RPSGT; Ivani C Trombetta, PhD; Sean M. Caples, DO; Abu S. Shamsuzzaman, PhD; Jan Bukartyk, MSc; Tomas Konecny, MD; Apoor S. Gami, MD; Tomas Kara, MD, PhD; and Virend K. Somers, MD, PhD, FCCP

Background: The Berlin Questionnaire (BQ) has been used to identify patients at high risk for sleep-disordered breathing (SDB) in a variety of populations. However, there are no data regarding the validity of the BQ in detecting the presence of SDB in patients after myocardial infarction (MI). The aim of this study was to determine the performance of the BQ in patients after MI.

Methods: We conducted a cross-sectional study of 99 patients who had an MI 1 to 3 months previously. The BQ was administered, scored using the published methods, and followed by completed overnight polysomnography as the “gold standard.” SDB was defined as an apnea-hypopnea index of ≥ 5 events/h. The sensitivity, specificity, and positive and negative predictive values of the BQ were calculated.

Results: Of the 99 patients, the BQ identified 64 (65%) as being at high-risk for having SDB. Overnight polysomnography showed that 73 (73%) had SDB. The BQ sensitivity and specificity was 0.68 and 0.34, respectively, with a positive predictive value of 0.68 and a negative predictive value of 0.50. Positive and negative likelihood ratios were 1.27 and 0.68, respectively, and the BQ overall diagnostic accuracy was 63%. Using different apnea-hypopnea index cutoff values did not meaningfully alter these results.

Conclusion: The BQ performed with modest sensitivity, but the specificity was poor, suggesting that the BQ is not ideal in identifying SDB in patients with a recent MI.

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Abbreviations: AHI = apnea-hypopnea index; BQ = Berlin Questionnaire; MI = myocardial infarction; OSA = obstructive sleep apnea; PSG = polysomnography; SDB = sleep-disordered breathing

The Berlin Questionnaire (BQ) is an instrument used to identify patients at high risk for sleep apnea based on symptoms related to snoring and daytime sleepiness along with the presence of hypertension or obesity. Initial validation showed that the BQ has high sensitivity and specificity in a primary-care setting,¹ and although it is a commonly used screening tool to detect the risk for sleep-disordered breathing (SDB) in the clinical setting, its diagnostic performance has been variable depending on the study population.²

The prevalence of SDB is much higher in patients with established cardiovascular disease.^{3,4} However,

this condition is still underdiagnosed in patients after a myocardial infarction (MI).⁵ The gold standard for diagnosing SDB remains the attended overnight laboratory polysomnogram, which is expensive and not widely available.⁶ The BQ might be useful in identifying patients at high risk for SDB after MI. However, no data regarding the validity of this tool in this patient population are available. We sought to determine the diagnostic accuracy of the BQ compared with full polysomnography (PSG) in patients after MI. Our hypothesis was that the BQ is not a good discriminating tool in detecting SDB because of the high prevalence of obesity and hypertension in patients with MI.

Study Population

We conducted a cross-sectional study of 99 patients who had an MI 1 to 3 months previously. The attending physician made the clinical diagnosis of MI. Patients were identified during an in-hospital cardiology service admission for MI. Although consecutive patients were eligible, recruitment was based on availability of research personnel and patients consenting to participate. Patients were excluded if they were previously given a diagnosis of SDB and treated with continuous positive airway pressure. This study was approved by the Mayo Clinic Institutional Review Board (IRB# 2156-03), and all patients signed an informed consent. Data regarding timing of MI in these patients have been published earlier.⁷

The Berlin Questionnaire

The BQ consists of 11 questions grouped in three categories; each category is scored as either positive or negative based on patient answers. Patients are considered to be at high risk for sleep apnea if at least two of the three categories are positive as shown in Table 1. The patient is considered to be at low risk if fewer than two categories are positive. The BQ scoring algorithm⁸ as used in the instrument's original validation study¹ is presented in Table 1. The research staff handed a paper version of the BQ to the patient, who completed it just before the PSG. Scoring of the BQ was done while blinded to the results from the PSG.

Epworth Sleepiness Scale

All patients filled out the Epworth Sleepiness Scale, which is a simple subjective scale that measures daytime sleepiness.⁹ This test consists of eight questions of daily life activities, each scored from 0 (not at all likely to fall asleep) to 3 (very likely to fall asleep). The total score ranges from 0 to 24, and subjectively quantified sleepiness and excessive daytime sleepiness were defined as a score of ≥ 11 .¹⁰

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Affiliations: From the Division of Cardiovascular Diseases (Drs Sert Kuniyoshi, Zellmer, Calvin, Lopez-Jimenez, Albuquerque, Trombetta, Shamsuzzaman, Konecny, Gami, Kara, and Somers; Mr Bukartky; and Ms van der Walt) and Division of Pulmonary and Critical Care Medicine (Dr Caples), Department of Internal Medicine, Mayo Clinic and Foundation, Rochester, MN; and ICRC-Department of Cardiovascular Diseases (Dr Kara), St. Anne's University Hospital Brno, Brno, Czech Republic.

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Correspondence to: Virend K. Somers, MD, PhD, FCCP, Division of Cardiovascular Diseases, Mayo Clinic College of Medicine, 200 First St SW, Rochester, MN 55905; e-mail: somers.virend@mayo.edu

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Polysomnography

All patients underwent comprehensive, digital, full-night diagnostic PSG between 10:00 PM and 6:00 AM. Polysomnograms were recorded on an E-Series Comprehensive Networked-Linked Amplifier System for Sleep/EEG (Compumedics Ltd; Abbotsford, Victoria, Australia) or Siesta 802 wireless amplifier/recorder for ambulatory PSG and long-term electroencephalography (Compumedics Ltd). All polysomnograms were recorded through PSG Online 2 recording software and scored online during data acquisition using Profusion PSG 2 software (Compumedics Ltd). Airflow was monitored by nasal pressure transducer (integrated nasal pressure transducer with Pro-Tech Pro-Flow nasal cannulas) and oronasal thermocouple (Pro-Tech one-channel oronasal thermal airflow sensor) (Philips Respironics; Murrysville, Pennsylvania), and respiratory effort was monitored by calibrated respiratory impedance plethysmography (Summit IP Inductive Respiratory Effort system; Compumedics Ltd). During all PSG studies, the electroencephalogram, electrooculogram, and submental electromyogram were recorded with surface electrodes according to American Academy of Sleep Medicine standards.¹¹ Oxyhemoglobin saturation was recorded by finger pulse oximetry (E-Series integrated pulse oximetry and Siesta 802 integrated pulse oximetry; Compumedics Ltd) and standard lead I, II, and III of the ECG.

Polysomnograms were conducted and sleep stages, disordered breathing events, oxygen desaturation, and periodic limb movement scored by an experienced registered PSG technologist (C. v. d. W.). All PSG measurements and diagnoses were made blinded to the results of the BQ. Apneas were defined as a $\geq 90\%$ decrease of airflow for at least 10 s (as viewed on the thermal airflow channel), and hypopneas were defined by a $\geq 30\%$ decline in airflow for at least 10 s (as viewed on the nasal pressure channel) accompanied by an oxyhemoglobin desaturation of $\geq 4\%$. Apneas unaccompanied by evidence of respiratory effort were scored as central, whereas those accompanied by respiratory effort were labeled as obstructive. For the purposes of our study, mixed apneas were counted as obstructive. Arousals were considered respiratory related if associated with apneas, hypopneas, or other indicators of airflow limitation lasting at least 10 s but not meeting criteria for apneas or hypopneas. After classification, disordered breathing events were quantified by apnea-hypopnea index (AHI) and reported as the mean number of events per hour.

Statistical Analysis

Group means were tested for differences by two-sided *t* tests or Wilcoxon rank sum tests, depending on data distribution. Differences in proportions were tested by Fisher exact test, and continuous variables were compared by linear least squares regression. The sensitivity, specificity, positive and negative likelihood ratios, and positive and negative predictive values of the BQ were calculated. Receiver operating characteristic curve analysis was performed comparing clinical variables and BQ for the prediction of SDB, with results expressed as the area under the curve and 95% CI. Analyses were performed with JMP, version 7 (SAS Institute Inc; Cary, North Carolina). For all comparisons, *P* < .05 was considered significant.

RESULTS

Subject Characteristics

We recruited 99 patients (age, 62 ± 13 years; BMI, 30 ± 5 kg/m²; male sex, 81%; white, 99%). Prevalence of hypertension was 56%; hyperlipidemia, 63%; and diabetes, 22%.

Table 1—Berlin Questionnaire and Scoring Algorithm

Question	Responses	
Category 1: snoring positive if ≥ 2 points scored for the following items:		
1. Do you snore?	Yes	1
	No/do not know	0
2. If you snore, your snoring is:	Slightly louder than breathing	0
	As loud as talking	0
	Louder than talking	1
	Very loud, heard in adjacent rooms	1
3. How often do you snore?	Nearly every day	1
	3-4 nights/wk	1
	1-2 nights/wk	0
	1-2 nights/mo	0
	Never or nearly never/do not know	0
4. Has your snoring ever bothered other people?	Yes	1
	No/don't know	0
5. Has anyone noticed that you quit breathing during sleep?	Nearly every day	2
	3-4 times/wk	2
	1-2 times/wk	0
	1-2 times/mo	0
	Never or nearly never/do not know/refused	0
Category 2: daytime fatigue and sleepiness positive if ≥ 2 points scored for the following items:		
6. How often do you feel tired or fatigued after your sleep?	Nearly every day	1
	3-4 times/wk	1
	1-2 times/wk	0
	1-2 times/mo	0
	Never or nearly never/do not know/refused	0
7. During your wake time, do you feel tired, fatigued, or not up to par?	Nearly every day	1
	3-4 times/wk	1
	1-2 times/wk	0
	1-2 times/mo	0
	Never or nearly never/do not know/refused	0
8. Have you ever nodded off or fallen asleep while driving a vehicle?	Yes	1
	No	0
9. If so, how often does it occur?	Nearly every day	1
	3-4 times/wk	1
	1-2 times/wk	0
	1-2 times/mo	0
	Never or nearly never/do not know/refused	0
Category 3: is positive if ≥ 1 point scored for the following items:		
10. Do you have high BP?	Yes	1
	No/do not know	0
11. BMI, kg/m ²	> 30	1
	≤ 30	0

Overall classification: participant classified as high risk if two or more categories are positive, low risk if fewer than two categories are positive. (Adapted with permission from Reference 8.)

BQ Results

Of the 99 patients included in the study, the BQ identified 64 (65%) as being at high risk for sleep apnea. Sixty-four (65%) scored positively in category 1, 35 (36%) scored positively in category 2, and 75 (76%) scored positively in category 3.

PSG Results

SDB was present in 73% of the patients using an AHI cutoff point of ≥ 5 events/h. Using more conservative SDB definitions, AHI ≥ 15 events/h and ≥ 30 events/h, the prevalence of SDB in these patients after MI was still high (46% and 21%, respectively). Sleep efficiency was similar in patients with and without SDB ($71\% \pm 18\%$ vs $72\% \pm 20\%$, $P = .79$), and as expected, patients with SDB had a higher arousal index (42 ± 16 events/h vs 26 ± 15 events/h, $P < .01$), lower baseline oxygen saturation ($93\% \pm 3\%$ vs $94\% \pm 2\%$, $P = .04$), and lower nocturnal oxygen nadir ($79\% \pm 18\%$ vs $88\% \pm 4\%$, $P < .01$) than patients without SDB. Patients with SDB had higher BMI and higher triglyceride levels but were otherwise similar to those without SDB (Table 2).

Performance of the BQ

The sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios of a positive BQ to identify SDB in patients after MI are shown in Table 3. The overall diagnostic accuracy of the BQ for SDB using AHI cutoffs of 5, 15, and 30 events/h was 63%, 49%, and 44%, respectively.

We further investigated the diagnostic performance for components of the BQ, including each category or domain, snoring alone, obesity status alone and combined with snoring, and the severity of snoring (≥ 4 points was considered severe snoring), using an AHI cutoff of 15 events/h (Table 4). Accuracy of category 1, 2, and 3 of the BQ to detect SDB in patients after MI was 47%, 49%, and 52%, respectively. In fact, BMI alone was the factor that was most predictive in determining SDB status, with 56% accuracy for a BMI cutoff of ≥ 35 kg/m². We also investigated the prevalence of various possibilities that lead to high risk for SDB as detected by the BQ and found that 54% of the patients scored positive in the combination of categories 1 + 3, followed by 30% in categories 2 + 3 and 27% in categories 1 + 2.

DISCUSSION

Our results show that SDB is common in patients after MI and that the diagnostic performance of the

Table 2—Subject Characteristics

Characteristic	SDB Status		P Value
	SDB (n = 73)	No SDB (n = 26)	
Age, y	63 ± 12	59 ± 13	.16
Male sex	60 (82)	20 (78)	.57
BMI, kg/m ²	30 ± 5	28 ± 4	.01
High risk for SDB ^a	50 (68)	14 (54)	.23
Epworth Sleepiness Scale score	9.4 ± 4.2	8.2 ± 4.2	.20
Excessive daytime sleepiness ^a	26 (36)	8 (31)	.81
Left ventricular ejection fraction, %	50 ± 14	54 ± 11	.28
ST-elevated myocardial infarction	46 (71)	26 (81)	.26
Hypertension	42 (57)	14 (54)	.81
Hypercholesterolemia	46 (63)	16 (61)	.99
Diabetes mellitus	18 (25)	4 (15)	.41
Prior myocardial infarction	12 (16)	5 (19)	.76
Prior congestive heart failure	2 (3)	2 (6)	.27
Current smoker	17 (23)	12 (46)	.04
Systolic BP, mm Hg	119 ± 17	118 ± 23	.35
Diastolic BP, mm Hg	68 ± 11	67 ± 9	.73
Cholesterol, mg/dL	175 ± 42	172 ± 32	.69
Triglycerides, mg/dL	154 ± 112	107 ± 66	.02
High-density lipoprotein cholesterol, mg/dL	42 ± 11	41 ± 11	.84
Low-density lipoprotein cholesterol, mg/dL	104 ± 35	108 ± 32	.62
Fasting glucose, mg/dL	115 ± 22	114 ± 24	.88

Data are presented as mean ± SD or No. (%). SDB = sleep-disordered breathing (apnea-hypopnea index ≥ 5 events/h).

^aExcessive daytime sleepiness (Epworth Sleepiness Scale score ≥ 11).

BQ to screen for SDB in this population is very limited. To our knowledge, the present study highlights for the first time the issue of lack of sleepiness in the post-MI population, even though patients may have very severe SDB. The reason for this finding remains unclear, but the results are consistent with the lack of sleepiness evident in patients with heart failure with SDB.^{12,13}

The present study confirms a much higher prevalence of SDB in patients after MI (73% vs 24% reported in the general population).¹⁴ Our findings also are consistent with prior studies that showed a 66% prevalence of SDB in patients with acute coronary syndrome and acute MI.^{3,4} In fact, a recent prospective study found that middle-aged men with obstructive sleep apnea (OSA) were 68% more likely to develop coronary heart disease than those without OSA.¹⁵

The high prevalence of SDB in this population and the availability of effective treatment make identification of SDB in patients with cardiovascular disease critical, and a tool that effectively identifies patients

at risk for SDB would be useful in clinical practice. The results of the diagnostic performance of the BQ in patients after MI were disappointing. Whereas some studies have shown a good performance of the BQ in primary-care settings,¹ elective surgical patients,¹⁶ patients with atrial fibrillation,¹⁷ and patients with resistant hypertension,¹⁸ it has poor performance in identifying patients with OSA in a sleep clinic population.¹⁹ These differences may be related to the fact that the patients in the present study are older compared with prior studies,^{1,20} and screening tools and questionnaires may not have a good performance in elderly patients.²¹ It is also important to consider factors other than snoring and excessive daytime sleepiness during the evaluation of risk for SDB in patients after MI. For example, a recent study by Drager and colleagues²² reported the presence of metabolic syndrome as an important marker of OSA among patients with hypertension.

Because of the high prevalence of hypertension and obesity, the majority of patients (76%) scored

Table 3—Performance of the Berlin Questionnaire for the Prediction of SDB

SDB Criteria	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	LR+	LR−	Accuracy, %	ROC (95% CI), %
AHI ≥ 5	0.68 (0.58-0.77)	0.46 (0.36-0.56)	0.68 (0.58-0.77)	0.50 (0.25-0.43)	1.27	0.68	63	58 (0.48-0.68)
AHI ≥ 15	0.65 (0.55-0.74)	0.36 (0.26-0.45)	0.47 (0.37-0.57)	0.54 (0.44-0.64)	1.02	0.97	49	50 (0.40-0.59)
AHI ≥ 30	0.71 (0.62-0.79)	0.37 (0.27-0.46)	0.23 (0.15-0.31)	0.83 (0.76-0.90)	1.13	0.77	44	54 (0.44-0.64)

AHI = apnea-hypopnea index; LR− = negative likelihood ratio; LR+ = positive likelihood ratio; NPV = negative predictive value; PPV = positive predictive value; ROC = receiver operating characteristic. See Table 1 legend for expansion of other abbreviation.

Table 4—Questionnaire for the Prediction of SDB^a

	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	LR+	LR–	Accuracy, %	ROC (95% CI), %
Category 1	0.69 (0.60-0.78)	0.28 (0.19-0.37)	0.45 (0.35-0.55)	0.53 (0.43-0.63)	0.97	1.06	47	53 (0.43-0.63)
Category 2	0.33 (0.24-0.42)	0.64 (0.55-0.73)	0.45 (0.35-0.55)	0.52 (0.42-0.62)	0.92	1.05	49	50 (0.40-0.59)
Category 3	0.81 (0.73-0.89)	0.27 (0.18-0.36)	0.48 (0.38-0.58)	0.63 (0.53-0.73)	1.11	0.70	52	54 (0.44-0.64)
Snoring	0.76 (0.68-0.84)	0.26 (0.17-0.35)	0.46 (0.36-0.56)	0.57 (0.47-0.67)	1.03	0.91	49	50 (0.40-0.59)
BMI ≥ 30 kg/m ²	0.44 (0.34-0.54)	0.59 (0.49-0.69)	0.48 (0.38-0.58)	0.56 (0.46-0.66)	1.10	0.93	53	51 (0.41-0.61)
BMI ≥ 35 kg/m ²	0.17 (0.10-0.24)	0.89 (0.83-0.95)	0.56 (0.46-0.66)	0.56 (0.46-0.66)	1.53	0.93	56	54 (0.44-0.64)
BMI ≥ 30 kg/m ² + snoring	0.41 (0.31-0.51)	0.66 (0.57-0.75)	0.50 (0.40-0.59)	0.58 (0.48-0.68)	1.22	0.89	55	52 (0.42-0.62)
BMI ≥ 35 kg/m ² + snoring	0.15 (0.08-0.22)	0.89 (0.83-0.95)	0.53 (0.43-0.63)	0.55 (0.45-0.65)	1.36	0.95	55	53 (0.43-0.63)
Category 1 ≥ 4 points	0.17 (0.10-0.24)	0.76 (0.68-0.84)	0.35 (0.68-0.84)	0.51 (0.41-0.61)	0.63	1.14	47	55 (0.45-0.65)

See Table 2 and 3 legends for expansion of abbreviations.

^aSDB was defined as an AHI ≥ 15 events/h.

positively in category 3, and this could be one of the reasons why the BQ is not a good discriminating tool in this patient population. Moreover, 37% were misclassified with regard to SDB using the BQ, including 32% of those with SDB and 54% without SDB. Therefore, the BQ may not be an appropriate tool to use for either screening or risk stratification for SDB because of the high prevalence of SDB and its potential prognostic implications in this population. Given the lack of available screening tools, definitive testing of these patients with PSG or portable monitoring needs to be considered. However, it is unclear whether this strategy is feasible given the high cost of sleep studies, the lack of dedicated sleep centers, and the absence of data from randomized controlled trials showing that treatment of SDB in patients after MI confers significant benefit.⁶ As appreciation of the importance of SDB and its treatment evolve, further research into effective screening strategies will become even more important.

Limitations of our study include first, the small number of female patients, reducing our ability to determine whether BQ performance was gender related in this patient population. However, a prior study in patients referred to a sleep clinic showed that the BQ performs similarly in both men and women.¹⁹ Second, although there was no overt selection bias, we have to consider a possible participation bias because patients who had symptoms or thought they might have SDB may have been more likely to participate in our study. Finally, our study included predominantly older white men with acute MI identified from a cardiology service, which may limit the generalizability of our findings.

A key strength of our study is that all patients underwent a full-night diagnostic PSG, providing the gold standard against which we could compare the results of the BQ. The polysomnograms were interpreted by investigators blinded to the results of the BQ, and the BQ data were collected prior to the PSG and scored

using an algorithm not involving PSG measures. Therefore, interpretation of the risk for SDB by BQ was not influenced by the PSG results.

CONCLUSIONS

The present data show that SDB is very common in patients after MI. Identification of SDB in this population using clinical characteristics or validated questionnaires does not accurately identify patients at high risk for SDB or rule out SDB. The data reveal the need for more-accurate screening strategies for sleep apnea, especially in patients after MI. In the meantime, given the high prevalence of SDB and its likely consequences for long-term prognosis of patients after MI, definitive testing with PSG to detect and appropriately treat SDB is justifiable in this patient population rather than attempting to use a questionnaire-based screening tool to identify patients at high risk.

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Dr Sert Kuniyoshi: contributed to study design and concept, data acquisition, data analysis and interpretation, and drafting of the manuscript.

Dr Zellmer: contributed to data interpretation, critical revision, and approval of the manuscript.

Dr Calvin: contributed to data interpretation, critical revision, and approval of the manuscript.

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