# Accuracy of Respiratory Rate Measurements in Triage During Exercises of Mass Casualties

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## Abstract

Respiratory rate is one of the vital signs and determines the priority of patient disposition in any settings of emergency such as disasters or mass casualty incidents (MCIs). To assess the accuracy of measurements of respiratory rate in field triage (using Simplified Triage and Rapid Transportation, START), we compared the triage measurements of respiratory rate and criterion standard measurements of respiratory rate in consecutive subjects who have been assumed to be the victims of MCIs in 3 related exercises in 2004. After excluding those with missing measurements of respiratory rate, 96 subjects were enrolled for comparison between criterion standard measurements and triage measurements. Variability for triage staffs' measurements of respiratory rate was significantly lower than for criterion standard measurements of respiratory rate (SD 2.4 vs. 4.6; $P<0.05$). The sensitivity and specificity of triage measurement of respiratory rate in detecting bradypnea were 0% and 100%. The sensitivity and specificity of triage measurement of respiratory rate in detecting tachypnea was 54% and 93%, respectively. The correlation analysis showed unsatisfactory agreement between triage measurement of respiratory rate and criterion standard measurements of respiratory rate ($r^2=0.64$, 95% CI 0.49 to 0.78). Because of dependency on the value of respiratory rate, priority made by START can be easily changed. We thus emphasize that measurement of respiratory rate in field triage should be performed according to criterion standard.*(Ann Disaster Med. 2005;3:84-90)*

**Key words:** Respiratory Rate; Triage; Mass Casualty Incidents; Exercise

## Introduction

Respiratory rate is an important parameter in Simplified Triage and Rapid Transportation (START) which has been recognized as one of the best methods of triage in mass casualty incidents (MCIs). Although pulse oximetry has been accepted as an early claimant to the title of "fifth vital sign', it still cannot replace the measurement of respiratory rate.[1-4] Respiratory rate is the only vital sign measured clinically instead of electronically. The reliability of respiratory rate measurements are limited by several factors. Because of its role in determining diagnosis and ill severity, respiratory rate is essen-

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tial in prioritizing care after triage. However, as many studies showed,[1,5-7] there are always inaccuracy, poor inter-observer agreement, and low variability of routine measurements of respiratory rate.

START is an essential part of triage in the settings of disaster medicine. It is also practiced in almost each exercise of MCIs or disaster response. However, there are few studies concerning the variability or accuracy of triage measurements of respiratory rate relative to criterion standard measurements. However, low accuracy may indicate that triage measurements of respiratory rate are unlikely to detect clinically significant bradycardia or tachycardia, whereas low variability indicates that triage measurements of respiratory rate are more clustered than are criterion standard measurements of respiratory rate due to conscious or unconscious result selection. We therein designed the following prospective study to evaluate the accuracy of clinical measurements of respiratory rate in triage for MCI exercises which has been held in a university-teaching hospital.

## Methods

### *Study Protocol*

This study used a cross-sectional design to assess the accuracy of two methods of measuring respiratory rate and was approved by our Institutional Review Board. This study was conducted at a university-teaching hospital with an annual ED visits more than 80,000. Triage is performed independently of, and usually before, registration during exercises of MCIs.

Consecutive patients presenting to the triage area during designated periods of MCI exercises were enrolled in the study. Patients who were assumed to be in critical condition bypassed the triage area and were not enrolled. Pediatric patients (<15 years) were enrolled but were subsequently excluded from the data analysis.

As the so-called patients in the exercises entered the triage area, research assistants applied standard single-lead monitors (Philip Ltd., FL, USA). During the triage stage, triage staffs measured respiratory rate as part of standard triage assessment. The staffs were not aware that their measurements of respiratory rate were being collected for the study. The staffs were not able to see the electronic monitors or electronic measurement of respiratory rate collected from them.

At the end of the triage, research assistants immediately performed auscultation for 1 minute and observation for 1 minute to complete criterion standard measurements of respiratory rate. Research assistants were trained in standardized methods for collecting criterion standard measurements of respiratory rate, which they obtained by auscultation and then observation for 1 minute, respectively. Observation was performed as unobtrusively as possible, during a quiet period when the patient were asked to sit quietly, relax, not talk, and breathe normally. The stethoscope was applied in a single location. If auscultation and observation were obtained successfully, auscultation was the measurement used for data analysis. Observation was used for analysis in cases where auscultation was not performed. Research assistants also collected demographic data, presenting complaint, and time of presentation.

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### *Data analysis*

Variability's of triage staff measurements and criterion standard measurements of respiratory rate were estimated by calculating the SD of each measure. The *F* test was used to test if there were any statistically difference between these groups. The *F* test compares values for variance (the square of SD). Measurements were treated as unpaired.

The sensitivity and specificity for triage staffs' measurements of respiratory rate and criterion measurement of respiratory rate were calculated as follows. Triage measurements of respiratory rate were cross-tabulated against criterion measurements of respiratory rate. All of these values were categorized as low (<12 breaths/min), normal (12 to 20 breaths/min), or high (>20 breaths/min). These values were chosen as cut-off values according to commonly reported reference ranges.[2,8-11] Sensitivity and specificity for detecting bradypnea and tachypnea were calculated for triage measurements of respiratory rate with 95% confidence intervals (CIs).

We also performed correlation analyses comparing triage measurements of respiratory rate with criterion standard measurements of respiratory rate. The analysis examines the extent to which 2 methods of measurement of the same phenomenon are comparable each other and also how this level of agreement varies across the range of respiratory rate.[12] Data from pediatric patients were omitted from analysis because of the difference in reference ranges between adults and children. This decision was made after completion of data collection.

Microsoft Excel (Microsoft Co., Redmond, WA, USA) was used to produce the Bland-Altman analysis. The CIs and the F test were calculated using the software SSPS 10.0.

## Results

Ninety-six adult "patients" who attended 3 different exercises of disaster response in 2004 were enrolled in the study. Measurements of respiratory rate were missed in some patients. Missed triage measurements of respiratory rate occurred only when the triage staff left blank the box for recording the respiratory rate on the triage form. Missed criterion standard measurements of respiratory rate occurred because of the inabilities due to ongoing exercise. Comparison between criterion standard measurements and triage measurements were possible for 72 subjects. The mean age was 39$\pm$18 years and 31 of them were men.

The range of respiratory rates was 12 to 20 breaths per minute in triage group and was 10 to 23 breaths per minute in criterion group. Variability for triage staffs' measurements of respiratory rate was significantly lower than for criterion standard measurements of respiratory rate (SD 2.4 vs. 4.6; $P$<0.05). For triage measurements of respiratory rate, we determined sensitivity and specificity for detecting bradypnea and tachypnea relative to criterion standard 0% and 100% (Table). The sensitivity and specificity of triage measurement of respiratory rate in detecting tachypnea was 54% and 93%, respectively (Table).

The correlation analysis showed unsatisfactory agreement between triage measurement of respiratory rate and criterion standard measurements of respiratory rate ($r^2$=0.64, 95% CI 0.49 to 0.78) (Figure). These limits of agreement are wider than the range of normal respiratory rate values. Systematic bias was small for triage measurements of respiratory rate.

Subgroup analysis yielded results similar to those for the overall study but lacking in statistical significance. Variability was low for triage measurements of respiratory rate (SD 4.0)

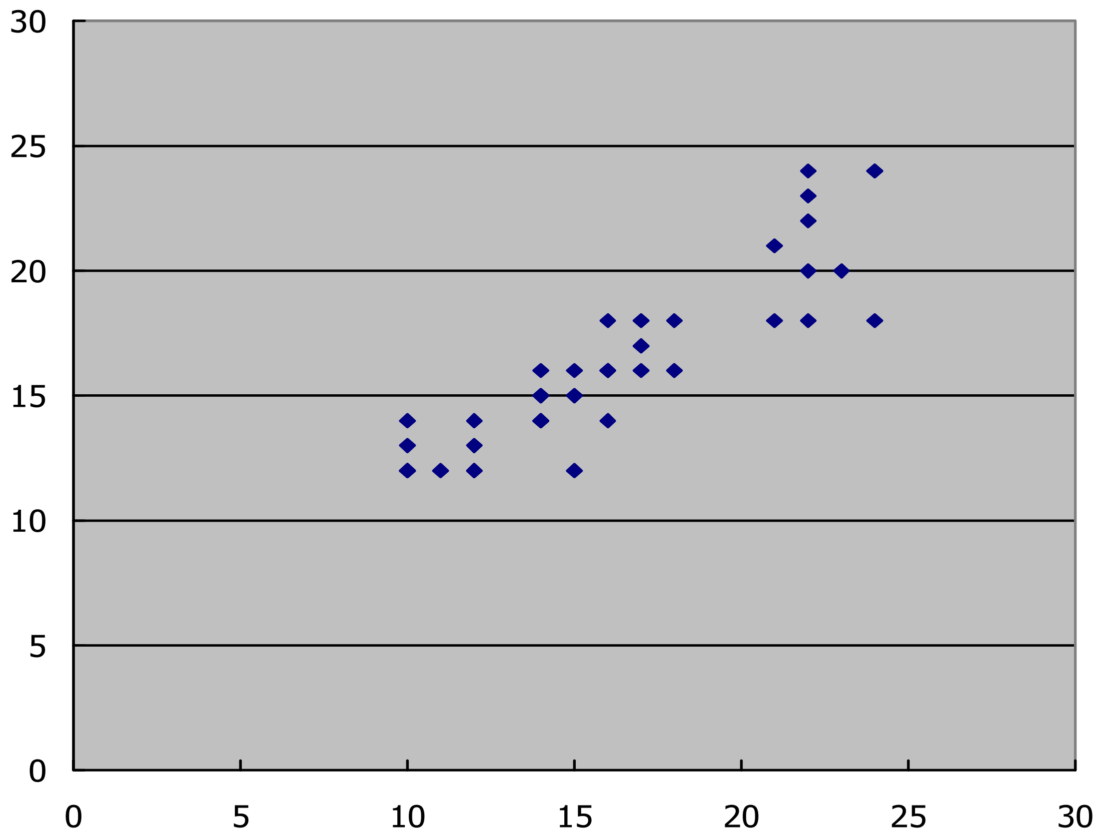


**Figure.** Scattered plots showing triage measurement of respiratory rate plotted against criterion standard measurement of respiratory rate ($r^2$=0.64)

**Table.** Cross tabulation of triage measurement of respiratory rate against criterion standard measurement of respiratory rate.
CSM: criterion standard measurement; TM: triage measurement

| Measurement, bpm | TM < 12 bpm | TM 12-20 bpm | TM >20 bpm | Total |
|---|---|---|---|---|
| CSM <12 bpm | 0 | 6 | 0 | 6 |
| CSM 12-20 bpm | 0 | 51 | 4 | 55 |
| CSM > 20 bpm | 0 | 5 | 6 | 11 |
| Total | 0 | 62 | 10 | 72 |

versus standard measurements of respiratory rate (SD 5.3; *P*=NS).

## Discussion

This study demonstrated that there was high inaccuracy in the measurements of respiratory rate during triage of MCI exercises. It is comparable to previous report concerning inaccuracy, poor inter-observer agreement and low variability of routine measurements of respiratory rate. [1,5-7]

When facing multiple victims in a MCI or a large-scaled disaster, the first responders such as emergency medical technicians or members of disaster medical assistance team should be familiar with a good triage system to fulfill such tasks. The so-called START method has gained popularity in recent years. The system takes into account the critical physiologic parameter such as the respiratory status, the perfusion, and the mental status of the patients and prioritizes patients into first priority (RED), second priority (YELLOW), third priority (GREEN), and expectant (BLACK).Our group ever demonstrated that tabletop exercises have several advantages over field operation drills. Using tabletop exercise can simulate the disaster or major incidents and evaluate critical knowledge and skills. The training model using START method in a tabletop exercise could significantly improve the triage ability and reduce over-triage and under-triage rate.[13] Respiratory rate is one of important parameters included in START. If respiratory rate is to be clinically useful, we must have meaningful reference ranges. Reports from as early as 1849 have studied respiratory rate ranges, yet such attempts have been beset by certain intrinsic problems. First, respiratory rate is probably more subject to voluntary control than any other vital sign. When subjects are aware that respiratory rate is being measured, the respiratory rate is sufficiently invasive or intrusive that they further influence respiratory rate.

The next is that it is to be expected that respiratory rate is context specific. Even when accounting for organic illness, sedated patients in an intensive care setting would be expected to have different ranges than clinic patients, people living their daily outside-of-hospital lives, people who are sleeping or crying, or patients attending a triage.

Even careful clinical measurement of respiratory rate, accepted as the criterion standard, has often been shown to have poor inter-observer agreement. In practice, triage respiratory rate measurement rarely meets the exacting requirements for accurate measurement. Some investigators have therein suggested that an alternative should be seeked. Respiratory rate is out of step with the other vital signs, which are measured electronically. There are many designed modalities[14-21] such as capnography, pneumotachography, acoustic monitoring by nasal microphones, fiberoptic nasal sensors, nasal thermistors, inductive plethysmography, mask-mounted pyroelectric polymer strips, single- or multi-compartment air mattresses, transdermal fiberoptic photoplethysmography, and transthoracic impedance plethysmography. However, in the field of disasters or MCIs, the electronic devices may be not practical and not available although all of the above modalities have been reported to correlate well with the standard method. Criterion standard measurements of respiratory rate still remain the useful method to measure and triage in the MCIs.

The discipline of disaster medicine places great emphasis upon the value of vital signs as tools for prioritizing care and for diagnosing and managing illness. Respiratory rate is as valuable as the other vital signs, yet the accuracy of its measurement lags behind. This problem deserves the attention and the energies of disaster rescuers and members. Because of dependency on the value of respiratory rate, priority made by START can be easily changed. We thus emphasize that measurement of respiratory rate in field triage should be performed according to criterion standard.

## References


1. Gravelyn TR, Weg JG. Respiratory rate as an indicator of acute respiratory dysfunction. JAMA 1980;244:1123-5
2. Harborne D. Measuring respiratory rate. Arch Emerg Med 1992;9:377-8
3. Mower WR, Sachs C, Nicklin El, et al. A comparison of pulse oximetry and respiratory rate in patient screening. Repoiratory Med 1996;90:593-9
4. Morley CJ, Thornton AJ, Fowler MA, et al. Respiratory rate and severity of illness in babies under 6 months old. Arch Dis Child 1990;65:834-7
5. Hooker EA, O'Brien DJ, Danzyl DF, et al. Respiratory rates in emergency department patients. J Emerg Med 1989;7:129-32
6. Edmonds ZV, mower WR, Lovato LM, et al. The reliability of vital sign measurements. Ann Emerg Med 2002;39:233-7
7. Huang C, Koulouris M, Singer A. Accuracy of automated triage vital signs [abstract]. Ann Emerg Med 2002;40:S87
8. Tintinalli JE, Kelen GD, Staczynski JS, eds. Emergency Medicine: A Comprehansive Study Guide. 6th ed. New York, NY: McGraw-Hill; 2003.
9. Gunn VL, Nechyba C, eds. The Harriet Lane Handbook: A manual for Pediatric House Officers. 16th ed. St. Louis, MO: Mosby; 2002:514
10. Luce JM. Respiratory monitoring in critical care. In: Goldman L, Bennet JC, eds. Cecil Textbook of Medicine. 21st ed. Philadelphia, PA: WB Saunders; 2000: 485
11. Mathers LH, Frankel LR. Stabilization of the critically ill child. In: Behrman RE, Kliegman RM, Jenson HB, eds. Nelson Textbook of Pediatrics. 17th ed. Philadelphia, PA: WB Saunders; 2004: 280
12. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1:307-10
13. Chen KC, Chen CC, Wang TL. The role of tabletop exercise using START in improving triage ability in disaster medical assistance team. Ann Disaster Med 2003; 1:78-84
14. Vegfors M, Ugnell H, Hõk B, et al. Experimental evaluation of two new methods for respiratory rate monitoring. Physiol Meas 1993;12:171-81
15. Egleston CV, Ben Aslam H, Lambert MA. Capnography for monitoring non-intubated spontaneously breathing patients in an emergency room setting. Emerg Med J 1997;14:222-4
16. Dodds D, Purdy J, Moulton C. The PEP transducer: a new way of measuring respiratory rate in the non-intubated patient

17. Manczur T, Greenough A, Hooper R, et al. The breathing parameters in young children: comparison of measurement by repiratory inductance plethysmography to a facemask pneumotachograph system. Pediatric Pulmonol 1999; 28:436-41
18. Marks MK, South M, Carter BG. Measurement ofrespiratory rate and timing using a nasal thermocouple. J Clin Monit 1995;11:159-64
19. Hõk B, Wilklund L, Henneberg S. A new respiratory rate monitor: development and initial clinical experience. Int J Clin Monit 1993;10:101-7
20. Marks MK, South M, Carlin JB. Reference ranges for respiratory rate measured by thermistry (12-84 months). Arch Dis Child 1993; 69:569-72
21. Vegfors M, Lindberg L, Pettersson H, et al. Presentation and evaluation of a new optical sensor for respiratory rate monitoring. Int J Clin Monit Comput 1994;11:151-6