# Satisfaction of Search for Subtle Skeletal Fractures May Not Be Induced by More Serious Skeletal Injury

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**Purpose:** The aim of this experiment was to test whether radiographs of major injuries, those having serious consequences for life and limb, produce a satisfaction-of-search (SOS) effect on the detection of subtle, nondisplaced test fractures.

**Methods:** Institutional review board approval and informed consent from 24 participants were obtained. Seventy simulated patients with multiple trauma injuries were constructed from radiographs of 3 different anatomic areas demonstrated only skeletal injuries. Readers evaluated each patient under 2 conditions: first, in the non-SOS condition, no injuries were present in the first anatomic images, and second, in the SOS condition, the first anatomic images included major injuries requiring immediate medical intervention. The SOS effect was measured on detection accuracy using receiver operating characteristic analysis for subtle test fractures presented on examinations of the second or third anatomic areas.

**Results:** Satisfaction-of-search reduction in receiver operating characteristic experiments for detecting subtle test fractures with the addition of a major injury was not observed.

**Conclusions:** Satisfaction of search was absent when major injuries were presented on radiographs. This finding rejects the hypothesis that SOS arises primarily from injuries requiring major intervention. Similar results have been found previously when major injuries were presented on CT but test fractures were presented on radiographs. This new finding rejects the possibility that SOS is absent because added and test fractures appear on different imaging modalities.

**Key Words:** Diagnostic radiology, observer performance, images, interpretation, quality assurance

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## INTRODUCTION

The satisfaction of search (SOS) effect, whereby one abnormality is missed in the presence of another, contributes to false-negative errors in radiology. An experimental paradigm for studying SOS in patients with multiple organ trauma has been used in 2 receiver operating characteristic (ROC) experiments. Trauma patients often require a series of radiographs to evaluate all potentially damaged organs. In a 1994 study, the detection of subtle test fractures was substantially reduced when other injuries were included in the case series [1]. In a second study in 2007, the SOS effect was again demonstrated in patients with multiple trauma using modern digital acquisition and display methods [2]. The reduction in performance was about the same in both studies: a reduction in ROC curve area for detecting test fractures from 0.86 to 0.81 ($P < .01$). In both studies, the test fractures and other injuries were not serious and did not require immediate medical intervention.

It has long been suspected that a cause of diagnostic oversight in multiply injured patients is the immediate need to treat life-threatening injuries [3,4]. Therefore, the hypothesis that injuries having immediate implications for patient care should have stronger SOS effects

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than less serious injuries was tested in a third ROC experiment [2]. This experiment did not find a significant SOS reduction in detecting test fractures on radiographs of other body parts, perhaps because a majority of the major injuries were shown in most cases with CT, while the test fractures were shown on radiographs. The absence of an SOS effect possibly could be explained as an effect that does not extend across imaging modalities.

Using a new group of radiology readers, this experiment tested whether major injuries, with serious consequences for life and limb but presented only on radiographs, produce a SOS effect on the detection of subtle, nondisplaced test fractures.

## METHODS

In the SOS paradigm that has been used in laboratory experiments, a known abnormality is defined as the test abnormality because the detection of that abnormality is measured. The test abnormality is always presented twice to observers: once alone and once with another abnormality within that same examination. Table 1 presents the SOS paradigm and terminology. Satisfaction of search occurs when a test abnormality is missed in the presence of a distracting abnormality but not in its absence. Although the detection of any abnormality may affect the detection of any other abnormality, SOS can be measured rigorously only on the test abnormality because it is the only abnormality that is presented by itself as a critical control condition.

In the current experiment, as in previous experiments testing SOS effects in skeletal trauma radiology, radiographic examinations of 3 anatomic areas were presented for each simulated patient. There were 2 experimental conditions; the first examination displayed was normal for the non-SOS control condition but displayed a major injury in the SOS condition. The addition of injuries into the first examination was an experimental manipulation; we measured detection of the test fractures appearing in the second or third examinations and gathered false-positive responses when both the second and third examinations were normal.

### Imaging Material

Digital radiographs were collected from existing records and identified only with alphanumeric codes. Use of these images complied with federal guidelines protecting individual identities and was approved by our institutional review board as compliant with Exemption 4 under National Institutes of Health rules. They were converted from DICOM format to tagged image file format and optimally resized to fill the display screen.

### Simulated Multitrauma Patients

Seventy cases were constructed to simulate patients with multiple injury trauma. Each case depicted a series of examinations using only skeletal radiographs from 3 different body parts. A case was presented in a specific order so that the major injury could appear only as the first examination and the test fracture could appear as either the second or third examination of the series. This display procedure ensured that images with major injuries would appear before those with test fractures. The radiographs from 304 unidentified patients presenting >800 normal or abnormal examinations were used in the simulations. Although the examinations simulating each patient came from different sources, they were matched so that they would seem to belong to the same individual. To the extent possible, we used examinations from the same patient. When this was not possible, we matched examinations by gender and age. The truth status of the cases was rigorously confirmed by 2 senior skeletal radiologists with 15 and 37 years of experience. They also

**Table 1.** The two treatment conditions of the SOS paradigm

| SOS Terminology<br>Paradigm design | Non-SOS Condition<br>Control | | SOS Condition<br>Experimental | |
|---|---|---|---|---|
| 70 patients viewed twice, once in each condition | 43 patients | 27 patients | 43 patients | 27 patients |
| First examination in the patient series: does it contain a major added injury? | No | No | Yes | Yes |
| Second and third examinations of the patient: does one of the two examinations contain a test fracture? | Yes | No | Yes | No |
| Parameter measured at each ROC point: rating thresholds 5/4321, 54/321, 543/21, and 5432/1 | TPF | FPF | TPF | FPF |
| Accuracy parameter: AUCs for each of 24 readers in each condition | Non-SOS AUC | | SOS AUC | |
| SOS effect = non-SOS AUC − SOS AUC (assessed with DBM MRMC) | Generalization to population of readers (Readers treated as a random effect) | | | |

Note: AUC = area under the receiver operating characteristic curve fitted by the proper contaminated binormal receiver operating characteristic model to the (FPF, TPF) coordinates for each reader-treatment combination; DBM = Dorfman-Berbaum-Metz methodology; FPF = false-positive fraction (1 − specificity); MRMC = multireader, multicase methodology; SOS = satisfaction of search; TPF = true-positive fraction (sensitivity). The terminology associated with the SOS experimental paradigm relates chiefly the distinction between test fractures and added fractures. We measured the former and manipulated the latter. The manipulation creates the experimental conditions: no added abnormality (non-SOS condition) and added abnormality (SOS condition).