Screening for pressure ulcer risk in an acute care hospital: Development of a brief bedside scale

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Received 17 March 2001; received in revised form 5 September 2001; accepted 12 November 2001

Abstract

To derive a brief bedside pressure ulcer prediction tool for patients admitted to acute care hospitals, we conducted a prospective study of first pressure ulcer incidence among 1,190 consecutive patients hospitalized in selected wards of a Swiss teaching hospital. Baseline predictors included patient age and items from the Norton and Braden ulcer prediction scales. During follow-up, 170 patients developed new pressure ulcers. The predictive ability of baseline assessments decayed over time. Occurrence of first pressure ulcer in the 5 days after admission (129 events) was best predicted by patient age (5 levels), mobility (3 levels), mental status (3 levels), and friction/shear (3 levels). The Fragmment score (sum of friction, age, mobility, mental status) was linearly related to pressure ulcer risk, and its area under the receiver operating characteristic curve (0.80) was higher than for the Norton (0.74; \(P=0.006\)) and Braden (0.74; \(P=0.004\)) scores. This brief pressure ulcer prediction scale performed well in an acute care setting. Use of this scale may facilitate the implementation of pressure ulcer prevention interventions. © 2002 Elsevier Science Inc. All rights reserved.

Keywords: Pressure ulcers; Prediction scales; Acute care hospitals; Quality of health care

1. Introduction

Pressure ulcers are an unpleasant and costly complication of hospitalization [1–3]. Although many pressure ulcers are preventable [4–6], many health care facilities lack a systematic approach to avoiding this complication [7–9]. Such an approach should include screening of admitted patients for existing ulcers and for increased risk of developing a pressure ulcer, implementation of preventive interventions for those afflicted or at risk, monitoring of skin status, and early treatment should a pressure ulcer occur.

This paper addresses the issue of screening. Screening tools have been available since the 1960s, including the Norton [10] and the Braden [11] scales, which have been recommended for use by the Agency for Health Care Policy and Research [6]. However, these tools have been intended primarily for use in nursing homes, and their content and scoring schemes were determined by expert opinion and literature review, not by empirical data [12]. Hence, these instruments may not be optimal for acute care settings, even though their application in hospitals is expanding [13–17]. Several studies have reported that all items belonging to a given risk-assessment scale are not equally strongly associated with pressure ulcer prevalence [14–15] or incidence [16].

In this paper, we describe the development of a brief bedside screening tool, based on the broadly recommended Norton and Braden scales, intended for detection of pressure ulcer risk in acute care settings.

2. Methods

2.1. Study design and setting

A prospective study was conducted between March and June 1997 at the Geneva University Hospital, a 1,100-bed teaching hospital, in departments where the prevalence of pressure ulcers was moderate to high in previous cross-sectional studies [15,17]: internal medicine, abdominal sur-
gery, orthopedics, neurosurgery, intensive care, and dermatology. As a quality improvement project devoid of active patient participation beyond usual care, the project was approved by the hospital medical director’s office, not by the hospital ethics committee. At the time of study, the hospital had no systematic policy of screening for pressure ulcer risk among admitted patients.

2.2. Study variables

The outcome variable was the occurrence of a first pressure ulcer, acquired in hospital, of stage 1 or greater (stage 1: nonblanching erythema; stage 2: superficial erosion; stage 3: full-thickness skin loss; stage 4: breach of underlying fascia or other deep structures) [18].

Baseline predictors considered for inclusion in the screening tool included patient age and sex and all items in the Norton [10] and Braden [11] scales. The Norton scale includes mobility, activity, physical status, mental status, and incontinence; the Braden scale includes mobility, activity, skin moisture, dietary intake, sensory perception, and friction/shear. Mobility and activity items appear in both scales; therefore, there are a total of nine distinct items. For both scales, items are scored between 1 (worst) and 4 (best), except friction/shear, which is scored from 1 to 3. Items are added to form the global score, which ranges from 5 to 20 for the Norton scale and from 6 to 23 for the Braden scale. The levels of each item are described by short phrases (Norton scale) or one-paragraph descriptions (Braden scale) [6]; we used the fuller Braden scale descriptions for the two shared items (activity and mobility).

To better understand the role of preventive activities, we recorded the following: recourse to periodic repositioning (every 2 hours), use of pressure-reducing devices (pillows, mattresses, beds), and dates when these interventions were started and stopped.

To obtain a simple tool that could be used by nurses at the bedside, we did not consider potential predictors that require access to medical records or that depend on medical decisions; we restricted our analysis to patient demographics and the content of Norton and Braden scales. Thus, medical diagnoses (including the Charlson comorbidity score [19]) and treatments were analyzed as additional predictors but were not considered for inclusion in the prediction scale.

2.3. Data collection

Data were collected on standard forms by a team of research nurses who were trained before the study in the application of the Braden and Norton scales and in ulcer staging. All patients newly admitted to participating wards on preselected days underwent a baseline assessment upon admission and were followed thereafter twice per week for up to 3 weeks. Items for the Norton and Braden scales; the presence, grade, and date of occurrence of pressure ulcers; and the use of preventive interventions were assessed by the research nurses based on review of nursing records, interview of each patient’s nursing team, and, if necessary, direct patient observation. Demographic, clinical, and treatment-related variables were abstracted from nursing and medical records.

2.4. Analysis

Because patients can leave the hospital at any time, we explored relationships between baseline predictors and occurrence of pressure ulcers using Kaplan-Meier and proportional hazards models [20]. The observation ran from the day of the baseline assessment to either the day of occurrence of the first pressure ulcer or to the day of the last assessment if no pressure ulcer occurred. Patients who were seen only once were awarded a half day of follow-up to permit inclusion of new pressure ulcers that appeared in hospital on the day of the baseline assessment. In selecting the best multivariate model, we treated the nine Norton-Braden prediction items as continuous variables, both to limit the number of degrees of freedom spent on each model and to test the hypothesis of a dose-dependent relationship between item and pressure ulcer risk. The best multivariate model was constructed in a stepwise manner, under analyst control (not by automated algorithm). This model was re-run with predictors coded into discrete variables (3 degrees of freedom for each four-level item) to provide a basis for the final simplified instrument. Points awarded to each level of risk were approximately proportional to the corresponding adjusted regression coefficient.

Proportional hazards models were compared by log-likelihood statistics (goodness of fit). We also replicated multivariate models using logistic regression, with pressure ulcer occurrence as the dependent variable, constructed receiver operating characteristic (ROC) curves for each test score [21], and computed areas under the curve (AUC). The interpretation of an AUC is as follows: If one patient without a pressure ulcer and one with a pressure ulcer are selected at random, the AUC corresponds to the probability that the patient with the ulcer has the higher test score; a perfect test has an AUC of 1, a worthless test an AUC of 0.5. Confidence intervals on AUCs were constructed from 250 bootstrap replications using the bias-adjusted percentile method [22], and differences between predictive scores were tested using a paired test [23].

To check for overfitting of the selected score to the study sample, we performed a cross-validation procedure [22,24]. The sample was split into 10 random subsamples. A logistic regression model was derived from nine tenths of the sample (derivation set), and the resulting regression equation was applied to the remaining tenth (validation set); this was repeated 10 times, each time rotating the validation subsample. The area under the ROC curve obtained by this procedure was compared with that obtained for a model obtained without cross-validation. This method makes more efficient use of the data than merely splitting data into the development and validation subsamples [24].
3. Results

3.1. Enrollment and follow-up

We included 1,190 patients. The baseline assessment took place on the day of admission for 508 patients (43%), on the next day for 484 patients (41%), and later for 198 patients (17%); the mean delay was 0.8 days. There were on average 3.4 assessments per patient: ≥1 assessments for 1,190 patients, ≥2 for 1,045 (88%), ≥3 for 805 (68%), ≥4 for 582 (49%), and ≥5 for 275 (23%) patients. The observations totaled 10,415 patient-days.

3.2. Baseline characteristics

Mean patient age was 61.4 years (range, 16–96; standard deviation [SD], 19.1; quartiles 49, 65, and 76 years), and 540 patients were women (45%). The admission ward was internal medicine for 427 patients (36%), abdominal surgery for 285 (24%), orthopedics for 188 (16%), neurosurgery for 131 (11%), intensive care for 118 (10%), and dermatology for 41 (3%). Regarding comorbidity on admission, 530 patients (45%) had a Charlson score of 0, 423 (36%) had a Charlson score of 1–2, and 237 (20%) had a Charlson score of 3–14. During their hospital stay, 55 patients (5%) died, 378 (32%) underwent surgery, 201 (17%) were put in a cast or another containment device, and 171 (14%) were treated in intensive care units.

3.3. Pressure ulcers

On admission, 27 patients (2%) bore 41 pressure ulcers. Twenty-two ulcers were in stage 1, 9 were in stage 2, 5 were in stage 3, and 4 were in stage 4. These ulcers were not considered in the analysis of pressure ulcer incidence. Following admission, 356 new pressure ulcers (34 per 1,000 patient-days) appeared in 182 patients (15%). The number of pressure ulcers per patient was 1 (83 patients), 2 (47 patients), 3 (34 patients), 4 (13 patients), or 5 (5 patients). At the time of their discovery, 302 ulcers were in stage 1 (85%), 48 were in stage 2 (13%), 4 were in stage 3 (1.1%), and 2 were in stage 4 (0.6%). Of the 182 first hospital-acquired ulcers, 12 were excluded from further analysis because they appeared before the day of the baseline assessment.

3.4. Incidence of first pressure ulcers

To develop a pressure ulcer risk assessment tool, we considered only first pressure ulcers. Censoring observations at the time of first ulcer occurrence left 8,586 patient-days of follow-up. The global incidence rate was 170/8,586, or 20 first pressure ulcers per 1,000 patient-days (95% confidence interval [CI], 17–23 per 1,000 patient-days). The hazard of a first pressure ulcer declined gradually from the first days of hospitalization (Table 1). Furthermore, the ability of baseline Norton and Braden scores to predict occurrence of first pressure ulcers also decayed over time (Table 1). The predictive ability of these scales was similar.

3.5. Selection of items for a brief screening scale

Because pressure ulcer prediction appeared to be limited in time, we restricted further modeling of pressure ulcer risk to the first 5 days of observation, during which 129 first pressure ulcers occurred. In univariate proportional hazards analysis, age exhibited a strong and gradual relationship to risk of pressure ulcer within 5 days (Table 2). Of the nine Norton-Braden items, all but “skin moisture” were significantly linearly associated with ulcer occurrence. In multivariate analysis, age remained a strong predictor in all models. Having included age, baseline assessments of mobility (P = 0.006), mental status (P = 0.059), and friction/shear (P = 0.034) remained linearly associated with subsequent ulcers (Table 2). We decided to retain the mental status item despite its borderline significance, bearing in mind the limited power of our study and the arbitrary nature of the P = 0.05 cutoff.

3.6. The Fragmment scale

The same four-variable model was rerun with each Norton-Braden item modeled as a discrete ordinal variable, thus using 15 degrees of freedom instead of 7 (Table 3). The coding scheme for the proposed instrument was derived from this model, associating each response with a score approximately proportional to the corresponding regression coefficients, while preserving simplicity. The purpose was to allow computation of the overall score by adding scores of the four items. As a mnemonic device, we called this instrument the “Fragmment scale” (friction/shear, age, mobility, mental status). Items for mobility and mental status were recoded into three levels by grouping the two lowest levels of risk, whereas friction (three levels) and age (five levels) retained their original coding scheme; for all items, low risk was represented by a low score. The linearity of this coding scheme with regard to pressure ulcer risk appeared to be satisfactory (Table 3). Confirming the success of this coding, the proportion of patients who developed a pressure ulcer increased progressively with higher baseline Fragmment scores (Fig. 1). On average, a one-point difference in the Fragmment scale was associated with a relative risk of 1.6 (95% CI, 1.4–1.7). In our sample, the mean Fragmment score was 2.0, and the SD was 2.1.

The analysis of various cutoff values for the Fragmment score indicated that although prediction of pressure ulcers was far from perfect, a reasonable compromise for clinical applications could be reached (Table 4). For instance, if scores 0–3 defined low risk, 80% of patients would be assigned to this group, and among them, 95% (negative predictive value) would not develop a pressure ulcer. Among the 20% defined as being at high risk, one third (positive predictive value) would develop a pressure ulcer within 5 days. If patients labeled as being at high risk were subjected to a preventive intervention, this strategy could prevent at the most 62% of pressure ulcers (sensitivity) and would involve 15% (complement of specificity) of patients who do not need it.
3.7. Cross-validation and scale comparison

The AUC for the Fragmment score was 0.80 (95% CI, 0.77–0.84) for the original dataset and 0.79 (95% CI, 0.75–0.82) for the cross-validation dataset, demonstrating minimal over-adjustment to the development sample. For comparison, the AUCs were significantly smaller for the Norton (0.74; 95% CI, 0.70–0.78) and Braden (0.74; 95% CI, 0.70–0.78) scales (P < 0.006 and 0.004, respectively, for comparison with Fragmment scale). These differences remained significant when cross-validated data were used (both P < 0.01). In corresponding proportional hazards models, the likelihood ratio statistic assessing model fit was 96.6 for the Norton scale, 94.5 for the Braden scale, and 153.9 for the Fragmment scale.

3.8. Subgroup analyses

We examined the robustness of predictions based on the Fragmment scale in selected subgroups of patients (Table 5). The relative hazard associated with a one-point increase in the Fragmment score ranged between 1.4 and 1.6 across subgroups.

3.9. Effect of prevention

Overall, 288 patients received one or more preventive interventions (regular change in position or special pillow, mattress, or bed) during the first 5 days and before the occurrence of the pressure ulcer in those who developed one, whereas 902 patients received no prevention. Among those subjected to prevention, the mean baseline Fragmment score was higher (3.5 versus 1.6; P < 0.001), and more patients developed a pressure ulcer within 5 days (66/288 [23.8%] versus 902 patients [9.2%]).
sus 61/902 [6.8%]; P < 0.001). Prevention was strongly associated with the risk of pressure ulcer in univariate analysis (odds ratio [OR], 3.5; 95% CI, 2.5–4.9) but not after adjustment for the Fragmment score (OR, 1.4; 95% CI, 0.9–2.1).

As expected, preventive activities reduced the predictive ability of the risk scale. The relative hazard associated with a one-point difference in the baseline Fragmment score was 1.7 (95% CI, 1.6–1.9) in absence of prevention and 1.3 (95% CI, 1.2–1.5) in presence of prevention. This difference in predictive ability was statistically significant (P < 0.001).

3.10. Other relevant predictors

When constructing the Fragmment screening scale, we excluded a priori data that required medical examination or decision-making, such as diagnoses and treatments. We added such variables to a subsequent multivariate model. Additional independent risk factors for pressure ulcers were having undergone surgery (adjusted relative hazard, 1.7; 95% CI, 1.1–2.7), being immobilized in a cast of other orthopedic device (adjusted relative hazard, 1.9; 95% CI, 1.2–

<table>
<thead>
<tr>
<th>Subgroups</th>
<th>Relative hazard per point of Fragmment score</th>
<th>95% CI</th>
<th>P value on interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>1.6</td>
<td>1.5–1.8</td>
<td>0.13</td>
</tr>
<tr>
<td>Men</td>
<td>1.5</td>
<td>1.3–1.6</td>
<td></td>
</tr>
<tr>
<td>Age group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16–59 y</td>
<td>1.4</td>
<td>1.2–1.7</td>
<td>0.44</td>
</tr>
<tr>
<td>60–79 y</td>
<td>1.6</td>
<td>1.4–1.9</td>
<td></td>
</tr>
<tr>
<td>80–96 y</td>
<td>1.5</td>
<td>1.3–1.7</td>
<td></td>
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<td>Charlson score</td>
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<td></td>
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<tr>
<td>0</td>
<td>1.5</td>
<td>1.4–1.7</td>
<td>0.81</td>
</tr>
<tr>
<td>1–2</td>
<td>1.5</td>
<td>1.4–1.7</td>
<td></td>
</tr>
<tr>
<td>3–14</td>
<td>1.6</td>
<td>1.4–1.9</td>
<td></td>
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<tr>
<td>Clinic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal medicine</td>
<td></td>
<td>1.5</td>
<td>1.4–1.7</td>
</tr>
<tr>
<td>Abdominal surgery</td>
<td></td>
<td>1.6</td>
<td>1.4–1.9</td>
</tr>
<tr>
<td>Orthopedics</td>
<td></td>
<td>1.5</td>
<td>1.4–1.7</td>
</tr>
<tr>
<td>Neuro-surgery/dermatology</td>
<td></td>
<td>1.6</td>
<td>1.1–2.4</td>
</tr>
<tr>
<td>Intensive care</td>
<td></td>
<td>1.4</td>
<td>1.1–1.7</td>
</tr>
<tr>
<td>Surgery</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Yes</td>
<td>1.5</td>
<td>1.4–1.7</td>
<td>0.38</td>
</tr>
<tr>
<td>No</td>
<td>1.6</td>
<td>1.4–1.8</td>
<td></td>
</tr>
<tr>
<td>Nursing workload*</td>
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<td>&lt;3 h/d</td>
<td>1.4</td>
<td>1.1–1.9</td>
<td>0.21</td>
</tr>
<tr>
<td>3-5 h/d</td>
<td>1.6</td>
<td>1.4–1.8</td>
<td></td>
</tr>
<tr>
<td>≥3 h/d</td>
<td>1.4</td>
<td>1.2–1.5</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: CI, confidence interval.
* Based on standard workload tool used by nursing department for personnel planning.

3.1. Charlson score

3.1.1, and a baseline Charlson comorbidity score ≥3 versus 0–2 (adjusted relative hazard, 1.8; 95% CI, 1.2–2.6). The adjusted relative hazard for a one-point difference in the Fragmment score was 1.5 (95% CI, 1.4–1.6). Likelihood ratio statistics, which reflect the relative contribution of each variable to overall model fit, were 125.4 for the Fragmment score, 6.1 for surgery, 7.8 for immobilization, and 7.7 for the Charlson comorbidity score. Other variables that were tested but did not remain in the final model were medications (curare, morphine, vasoactive drugs), route of nutri-

Table 4

<table>
<thead>
<tr>
<th>Fragmment scores defining low risk group</th>
<th>Patients in low risk group %</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive predictive value</th>
<th>Negative predictive value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>31.4</td>
<td>91.5</td>
<td>34.2</td>
<td>16.5</td>
<td>97.1</td>
</tr>
<tr>
<td>0–1</td>
<td>49.5</td>
<td>83.7</td>
<td>53.5</td>
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<td>96.4</td>
</tr>
<tr>
<td>0–2</td>
<td>66.6</td>
<td>76.7</td>
<td>71.9</td>
<td>24.9</td>
<td>96.2</td>
</tr>
<tr>
<td>0–3</td>
<td>79.9</td>
<td>62.0</td>
<td>85.0</td>
<td>33.5</td>
<td>94.9</td>
</tr>
<tr>
<td>0–4</td>
<td>86.6</td>
<td>49.6</td>
<td>91.0</td>
<td>40.3</td>
<td>93.7</td>
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<tr>
<td>0–5</td>
<td>90.5</td>
<td>40.3</td>
<td>94.3</td>
<td>46.0</td>
<td>92.9</td>
</tr>
<tr>
<td>0–6</td>
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<td>27.1</td>
<td>97.6</td>
<td>58.3</td>
<td>91.6</td>
</tr>
<tr>
<td>0–7</td>
<td>97.1</td>
<td>17.8</td>
<td>98.9</td>
<td>65.7</td>
<td>90.8</td>
</tr>
<tr>
<td>0–8</td>
<td>99.3</td>
<td>2.3</td>
<td>99.5</td>
<td>37.5*</td>
<td>89.3</td>
</tr>
</tbody>
</table>

* This value based on only eight patients who had scores ≥8.
4. Discussion

In this study, we used simple demographic data and items from existing pressure ulcer prediction scales (Norton and Braden scales) to develop a four-item instrument that can identify patients at increased risk of developing a pressure ulcer when admitted to an acute care hospital. The Fragmment scale should be easy to complete: One of the items is automatically available in patient records (age), and the others require only a brief assessment of three patient characteristics (mobility, mental status, and friction/shear), which can be completed at the bedside by a nurse or a physician.

The reduction in the number of items did not come at a cost of reduced predictive ability; rather, the opposite was the case. The improvement in predictive ability was both statistically and clinically significant. If one patient who will develop a pressure ulcer within 5 days and one patient who will not were selected at random, the odds are 4:1 that the patient who will develop the ulcer has a higher Fragment score, but the odds are 3:1 that this patient will have a higher Norton or Braden score. This improvement is due to the data-driven selection and scoring of items in our study. However, further improvement of pressure ulcer prediction tools remains possible. Additional risk factors for in-hospital pressure ulcers could be identified, and better scoring algorithms may be constructed using classification and regression trees or neural network methods (as in [25, 26]).

Fundamentally, the Fragment scale represents an evolution of the classic Norton and Braden scales. Its content validity is contingent on the work of Norton and Braden, as we did not attempt to identify risk factors that might have been missed by these precursors. We did not include items from some other scales because the consensus of professional bodies was that the Norton and Braden scales were the best available. The importance of patient age, the only item that we added, was recognized by Norton [27], Braden [28, 29], and others [3, 16, 30]. Inclusion of patient age as a predictor may not have been necessary in populations that are homogenous in terms of age, such as nursing home patients.

Even though item selection was not theory driven, three Fragment items (age, friction/shear, and mobility) explicitly fit current models of pressure ulcer causation [31]. Mental status is probably linked only indirectly with the pathogenesis of pressure ulcers; this variable may stand for other causal factors such as poor health, incontinence, or immobility. However, the prognostic value of poor mental health has been noted by others [13].

Because we aimed to obtain a simple bedside tool, the Fragment scale does not use all variables capable of predicting pressure ulcers; including data on comorbidities, surgical interventions and immobilization in a cast improved risk prediction. However, these variables cannot always be assessed at the bedside upon admission. Comorbidities and potentially useful laboratory tests [1, 3, 28, 30] may not be known until initial investigations are completed. The decision to perform surgery or to immobilize the patient may be taken at various points during the patient’s stay and may not always be known to all health care workers. However, inclusion of these and other additional predictors may prove both feasible and useful in some hospitals.

Cross-validation results indicated that our prediction model was not excessively over-fitted to the study sample. Furthermore, the stability of the predictive ability of the Fragment scale across patient subgroups and hospital wards strengthens the case that peculiarities of the study sample were not a major determinant of the choice of the model. Although the cross-validation demonstrated only that the prediction model was not overly affected by the selection of the study sample from the local patient population (i.e., internal validity), this procedure says nothing about the applicability of the instrument to other populations (i.e., external validity) [24]. The latter issue can be addressed only by replication of our findings in other settings. This would be all the more necessary because other researchers have selected other item sets for optimal pressure ulcer risk assessment [14–16]. Whereas the Fragment scale may be well suited for general acute care hospitals, we would not advise its use in nursing homes or other specialized settings.

A limitation of our study is that we did not assess the reliability of the Fragment scale. In this project, the primary source of information on the patient’s condition was his or her nursing team and nursing record, and duplicating these sources was not feasible. An ad-hoc reliability study should be conducted to check agreement obtained among members of the nursing team. Previous studies of interrater reliability of Norton-Braden items have yielded satisfactory results [16, 32]. Moreover, the good predictive value of the Fragment scale suggests that reliability could not have been unacceptably low.

We close with some recommendations on pressure ulcer screening in hospitals. The high incidence of pressure ulcers early after admission suggests that screening for pressure ulcer risk should occur immediately upon admission. Thereafter, risk assessment should be repeated regularly, at least every 5 days. Repeating assessments whenever the patient’s condition changes, such as after surgery, would seem reasonable. Finally, the risk assessment must be followed by appropriate action. This issue was not addressed in this study. One possibility, which is however not grounded in evidence thus far, would be to do nothing or apply minimal intervention only to patients at low risk (patients with Fragment scores of 0–3, who represented 80% of our sample), to implement standard prevention in patients with scores of 4–6 (15% of our sample), and more intensive preventive interventions among patients who have scores of 7–10 (5% of our sample). Any such strategies should be evaluated before they are integrated into routine practice.

Acknowledgments

Preliminary findings of this study were presented at the 1998 meeting of the International Society for Quality in Health
Care (Budapest, Hungary). This work was supported by the Quality of Care Program, Geneva University Hospitals.

References