Measure of Functional Independence Dominates Discharge Outcome Prediction After Inpatient Rehabilitation for Stroke

Allen W. Brown, MD; Terry M. Therneau, PhD; Billie A. Schultz, MD; Paulette M. Niewczyk, PhD, MPH; Carl V. Granger, MD

Background and Purpose—Identifying clinical data acquired at inpatient rehabilitation admission for stroke that accurately predict key outcomes at discharge could inform the development of customized plans of care to achieve favorable outcomes. The purpose of this analysis was to use a large comprehensive national data set to consider a wide range of clinical elements known at admission to identify those that predict key outcomes at rehabilitation discharge.

Methods—Sample data were obtained from the Uniform Data System for Medical Rehabilitation data set with the diagnosis of stroke for the years 2005 through 2007. This data set includes demographic, administrative, and medical variables collected at admission and discharge and uses the FIM (functional independence measure) instrument to assess functional independence. Primary outcomes of interest were functional independence measure gain, length of stay, and discharge to home.

Results—The sample included 148,367 people (75% white; mean age, 70.6±13.1 years; 97% with ischemic stroke) admitted to inpatient rehabilitation a mean of 8.2±12 days after symptom onset. The total functional independence measure score, the functional independence measure motor subscore, and the case-mix group were equally the strongest predictors for any of the primary outcomes. The most clinically relevant 3-variable model used the functional independence measure motor subscore, age, and walking distance at admission ($r^2=0.107$). No important additional effect for any other variable was detected when added to this model.

Conclusions—This analysis shows that a measure of functional independence in motor performance and age at rehabilitation hospital admission for stroke are predominant predictors of outcome at discharge in a uniquely large US national data set.

Key Words: nursing homes ■ rehabilitation ■ residence characteristics ■ treatment outcome

Approximately 795,000 people experience the first or recurrent stroke annually in the United States associated with an estimated combined direct and indirect cost of $38.6 billion.1 Because improved acute intervention improves stroke survival and the increasing average age of US citizens imparts age-related stroke risk to a greater percentage of the population, the need for hospital-based rehabilitation care will also increase. This will occur in a healthcare environment that has seen inpatient rehabilitation lengths of stay decrease from a mean of 28 days in 1989 to 16.5 days in 2007.2,3 Identifying clinical data acquired at inpatient rehabilitation admission that accurately predict key outcomes at discharge could inform the development of customized plans of care directed at affecting modifiable clinical predictors to achieve favorable rehabilitation outcomes and provide estimates of clinical, social, and other healthcare service needs in communities.

Previously identified factors predictive of outcome after inpatient rehabilitation for stroke have included various comorbid conditions, demographic information, social and vocational status, functional limitations, and stroke subtype.4-10 Many of these reports are limited by small sample sizes and single-center reviews, considering a restricted number of predictive variables.

The purpose of this analysis was to use a large comprehensive national data set, provided by the Uniform Data System for Medical Rehabilitation (UDSMR), to consider a wide range of clinical elements known at inpatient rehabilitation admission to identify those that predict functional gain, length of stay (LOS), and discharge to home.

Methods

The project was reviewed by the Institutional Review Board at Mayo Clinic. Deidentified data from inpatient rehabilitation facilities (IRFs) were obtained from the Uniform Data System for Medical Rehabilitation (UDSMR) that contains data collection from the Inpatient Rehabilitation Facility Patient Assessment Instrument. UDSMR is the world’s largest nongovernmental database on

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rehabilitation outcomes and represents ≈70% of the IRFs in the United States.

The sample data were obtained for individuals included in the UDSMR data set with the diagnosis of stroke for the years 2005 through 2007. Stroke cases were defined by the following International Classification of Diseases 9th edition Clinical Modification codes: 430; 432.0 to 432.9; 433.01 through 433.91; and 434.01 through 434.91. Patients with stroke were included if they were 18 years of age or older and were admitted for an initial rehabilitation from an acute care facility. Patients were excluded from the sample if they were not living at home before acute hospitalization or had an interruption in their rehabilitation stay.

The functional independence measure (FIM) instrument is the primary functional metric embedded in the Inpatient Rehabilitation Facility Patient Assessment Instrument. The FIM instrument is an 18-item tool that measures functional disability of individuals in terms of their need for assistance. The FIM instrument measures 2 unidimensional domains of motor function (13 items) and cognitive function (5 items). Each item is scored from 1 (total dependence) to 7 (total independence). The FIM instrument has been validated and shown to be reliable in multiple IRF populations, including the stroke population.13

Predictor variables collected at rehabilitation admission included age, sex, race, impairment code (right versus left body involvement), etiologic diagnosis (ischemic versus hemorrhagic), geographic region, total FIM score, FIM motor score, FIM cognitive score, impairment level (case-mix group), a calculated value considering the diagnosis requiring rehabilitation, FIM motor and cognitive scores, age, and comorbidities), FIM mobility mode (primary mobility mode walking versus wheelchair), FIM mobility score (ie, the score on the scale from 1–7), distance walked, marital status (married, not married), prehospital living-with and vocational categories, onset days (days from acute hospital admission to rehabilitation admission), primary payer, Commission on Accreditation of Rehabilitation Facilities accreditation status, and Joint Commission accreditation status. In addition and of primary interest were the predictive effects on outcome of newly acquired stroke-related comorbidities within the data set (dysphagia; undefined/dominant/nondominant hemiparesis/hemiplegia; undefined gait disorder; aphasia; ataxia; facial weakness; neglect; impaired visual fields; and neurogenic bladder). These comorbidities were identified by International Classification of Diseases 9th edition Clinical Modification codes reported in the Inpatient Rehabilitation Facility Patient Assessment Instrument as complications during the rehabilitation stay.

Outcomes of primary interest were FIM gain, LOS, and discharge living setting of home because they are important to individuals and their families and are often primary determinants of reimbursement.14

Statistical Analysis

The association between predictors and outcomes was assessed using generalized additive models.15 These allow for a smooth non-linear association between the predictor and the outcome and are more precise than simple linear or categorical predictions.16,17 This can be particularly important when assessing the effect of other variables in the presence of a strong primary predictor. Generalized additive model versions of linear regression were used for the continuous outcomes, and generalized additive model logistic models were used for dichotomous outcomes.

Concordance values were calculated for predictor and outcome pairs. For pairs of observations, the concordance (c-statistic) is defined as Prob(y2>y1|x2>x1), where y is the outcome and x is the predictor. A value of 50% indicates random predictions, and a value of 100 indicates perfect prediction. The c-index can be applied to both linear and logistic regression models; in the latter case, it is often referred to as the area under the receiver operating characteristic curve.18 Models were fit first to the baseline covariates identified below, and then the additional effect of each stroke-related comorbid condition was assessed by adding it to the model. The sample size is so large that any variable having an appreciable average effect on outcome (eg, changing the discharge FIM score by even 1 point) will be statistically significant at P≤0.01. We have omitted the P values from our results because they add no information—any relevant change is statistically reliable—and rather focused on reporting the effects and concordance.

The data were analyzed in aggregates without identification of individual hospitals or institutions. Individuals could not be connected to the hospital that contributed their data.

Results

Sample

Table 1 describes the entire sample of 148,367 subjects at rehabilitation admission and by stroke type. The population is dominated by white and elderly individuals who were admitted for inpatient rehabilitation with ischemic lesions (97%) and hemiparesis after just >1 week of acute hospitalization. The sample included cases from all US geographic regions (Table I in the online-only Data Supplement). Admission and discharge FIM scores are presented in Table 2 for the entire sample and by stroke type. The majority was admitted with moderately severe activity limitations (mean FIM total, 57), discharged ambulatory (overall mobility mode at discharge was walking for 85% of the sample and 79% were walking ≥50 feet) with moderate overall activity limitations (mean FIM total discharge, 81). Table 3 shows discharge outcomes, indicating that the majority of the sample were discharged home (70%) with a mean LOS of 16.5 days to live with others (71% of the sample), having gained an average of 24.1 FIM points.

Univariate Analyses

The effect sizes and concordance values for predictor variables and the outcomes of primary interest indicated that the best predictor for any particular outcome varies (Table II in the online-only Data Supplement). However, the FIM total and FIM motor variables, and case-mix group category were consistently the best predictors.

Multivariate Models

The variables of FIM total and FIM motor on admission and admission case-mix group were highly correlated, and models based on each of these were nearly equivalent in their predictive ability. Starting with each of these variables for each of the primary outcomes of interest, we examined all possible regressions that added either 1 or 2 predictor variables to this starting model. For all combinations, the best 3-variable model uses one of admission FIM total, admission FIM motor, or case-mix group, along with age and walking distance. Choosing between these 3 makes only a small difference as each is the best fit for one of the primary outcomes by a small margin. Because FIM motor is a primary determinant of functional independence, we focused on it as the final model for the rest of the analyses, but the results are not qualitatively changed by using another (Table III in the online-only Data Supplement, the concordance—c-statistic—for each model for the primary outcomes). A summary of the final 3-variable (admission FIM motor subscore, age, and walking distance) fit for the primary outcomes of interest is shown in Figures 1 to 3. In each figure, the graph of outcome versus FIM motor gives a baseline value, and those for age and walking distance...
Table 1. Sample Characteristics at Rehabilitation Admission

<table>
<thead>
<tr>
<th></th>
<th>Overall, n=148,367 (%)</th>
<th>Ischemic, n=144,266 (97)</th>
<th>Hemorrhagic, n=4,101 (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age, y, (SD)</td>
<td>70.6 (13.1)</td>
<td>70.6 (13.1)</td>
<td>69.9 (13.9)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing (%)</td>
<td>29 (0.02)</td>
<td>27 (0.02)</td>
<td>2 (0.05)</td>
</tr>
<tr>
<td>Female</td>
<td>76641 (52)</td>
<td>74835 (52)</td>
<td>1806 (44)</td>
</tr>
<tr>
<td>Marital status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married (%)</td>
<td>72,735 (56)</td>
<td>70,494 (49)</td>
<td>2,241 (55)</td>
</tr>
<tr>
<td>Not married:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>widow, divorced, single</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>18,703 (13)</td>
<td>18,138 (13)</td>
<td>565 (13)</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White (%)</td>
<td>108,387 (75)</td>
<td>105,436 (73)</td>
<td>2,951 (72)</td>
</tr>
<tr>
<td>Black</td>
<td>22,147 (15)</td>
<td>21,552 (15)</td>
<td>595 (15)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>7,551 (5)</td>
<td>7,305 (5)</td>
<td>246 (6)</td>
</tr>
<tr>
<td>Asian</td>
<td>5,507 (4)</td>
<td>5,344 (4)</td>
<td>163 (4)</td>
</tr>
<tr>
<td>American Indian, Hawaiian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>2,615 (2)</td>
<td>2,731 (2)</td>
<td>84 (2)</td>
</tr>
<tr>
<td>Impairment code</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left body/</td>
<td>62,326 (42)</td>
<td>61,029 (42)</td>
<td>1,297 (32)</td>
</tr>
<tr>
<td>right brain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>involvement (%)</td>
<td>62,117 (42)</td>
<td>60,905 (42)</td>
<td>1,212 (30)</td>
</tr>
<tr>
<td>Right body/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>left brain</td>
<td>47,000 (3)</td>
<td>4,444 (3)</td>
<td>256 (6)</td>
</tr>
<tr>
<td>involvement (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilateral</td>
<td>13,866 (9)</td>
<td>13,027 (9)</td>
<td>839 (20)</td>
</tr>
<tr>
<td>involvement (%)</td>
<td>53,585 (4)</td>
<td>48,611 (4)</td>
<td>497 (12)</td>
</tr>
<tr>
<td>Impairment severity stratification (CMG)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>101 least</td>
<td>73,435 (5)</td>
<td>71,113 (5)</td>
<td>230 (6)</td>
</tr>
<tr>
<td>impaired (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>11,328 (8)</td>
<td>11,033 (8)</td>
<td>295 (7)</td>
</tr>
<tr>
<td>103</td>
<td>2,377 (2)</td>
<td>2,272 (2)</td>
<td>105 (3)</td>
</tr>
<tr>
<td>104</td>
<td>20,058 (14)</td>
<td>19,505 (14)</td>
<td>553 (14)</td>
</tr>
<tr>
<td>105</td>
<td>16,858 (11)</td>
<td>16,375 (11)</td>
<td>483 (12)</td>
</tr>
<tr>
<td>106</td>
<td>15,753 (11)</td>
<td>15,353 (11)</td>
<td>400 (10)</td>
</tr>
<tr>
<td>107</td>
<td>13,852 (9)</td>
<td>13,459 (9)</td>
<td>393 (10)</td>
</tr>
<tr>
<td>108</td>
<td>9,417 (6)</td>
<td>9,193 (6)</td>
<td>224 (6)</td>
</tr>
<tr>
<td>109</td>
<td>11,521 (8)</td>
<td>11,212 (8)</td>
<td>309 (8)</td>
</tr>
<tr>
<td>110 maximally</td>
<td>39,860 (27)</td>
<td>38,751 (27)</td>
<td>1,109 (27)</td>
</tr>
<tr>
<td>impaired (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onset days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>8.2 (12)</td>
<td>8.1 (12)</td>
<td>12.5 (16)</td>
</tr>
<tr>
<td>Q1 (25th percentile)</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Q3 (75th percentile)</td>
<td>8</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Missing</td>
<td>1,695</td>
<td>1,660</td>
<td>35</td>
</tr>
</tbody>
</table>

CMG indicates case-mix group.

FIM Gain

As shown in Figure 1, FIM motor admission and walking distance have the greatest effect for predicting the outcome FIM gain, with a range of 9.1 and 8.9 FIM points, respectively, between the 10th and 90th percentiles.

Length of Stay

Figure 2 shows that FIM motor admission score has the greatest effect on LOS, with a difference of 10 days between the 10th and 90th percentiles when compared with just <4 days between the extremes of walking distance categories and ≥3 days between the 10th and 90th percentiles for age.

Discharge Home

For the outcome discharge to home, Figure 3 shows that the admission FIM motor score again had the greatest effect, with a 75% probability of discharge home for those at the 50% percentile.

No important additional effect on FIM gain was detected for any of the other predictor variables after accounting for the baseline model of FIM motor admission, age, and walking distance: the maximum predicted effect is 2.7 FIM points (dysphagia) and an increase in c-statistic of no more than 0.002. For LOS, there are a few predictors with a measurable clinical effect (eg, ≥21 day for the comorbidities of neurogenic bladder, neglect, and dysphagia), but all with an effect on the c-statistic of no greater than 0.001. This is in part because the total number of affected subjects is small, so that even if performance can be improved for those few, the effect of these stroke-related comorbidities on average predictive ability is extremely small (Table IV in the online-only Data Supplement shows the additional effect and c-statistic for other predictor variables beyond the final 3-variable model for ischemic stroke).

To look for variable interactions, we also fit the data using gradient boosting machine models. This is a sophisticated machine learning technique, which builds a complex model using a large number of simple tree models as components. The overall c-statistic for the gradient boosting machine model differed only trivially from the generalized additive model, confirming that interactions do not materially improve the fit. Median effects were also examined using quantile regression methods (data not shown), results differing only slightly from the reported analysis.

The models presented thus far predict the mean response for particular covariate combinations. In addition, a quantile regression model using the combined data set showed how the patient-to-patient variation in outcome also depends strongly on initial level of functional motor limitation (ie, FIM motor score). Although the average LOS rises with increasing functional limitation, there are individuals with shorter stays at all levels (Figure I in the online-only Data Supplement shows quantile regression of the continuous outcome FIM gain and LOS as a function of admission FIM motor score based on the combined data set including both ischemic and hemorrhagic events).
Table 2. Admission and Discharge FIM Scores

<table>
<thead>
<tr>
<th>Activity Element</th>
<th>Overall (n=148,367)</th>
<th>Ischemic (n=144,266)</th>
<th>Hemorrhagic (n=4,101)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIM total: mean (SD)</td>
<td>56.8 (19.5)</td>
<td>56.9 (19.4)</td>
<td>55.0 (19.8)</td>
</tr>
<tr>
<td>FIM motor: mean (SD)</td>
<td>36.4 (14.1)</td>
<td>36.4 (14.1)</td>
<td>36.3 (14.4)</td>
</tr>
<tr>
<td>FIM cognitive: mean (SD)</td>
<td>20.4 (7.9)</td>
<td>20.5 (7.9)</td>
<td>18.7 (7.9)</td>
</tr>
</tbody>
</table>

Discussion

The findings of this analysis indicate that functional status on rehabilitation hospital admission is a primary predictor of outcomes at discharge in a large nationally representative sample. This finding confirms similar reports from smaller clinical and convenience samples.6,21–23 Unique to this analysis was the inclusion of a broad range of clinical characteristics and stroke-related comorbid conditions that have previously been shown to be important in predicting outcomes (eg, urinary incontinence, stroke mechanism, social support, marital status, lesion hemisphere, and dysphagia). The UDSMR data set provided powerful analytic opportunities to demonstrate that none of these clinical characteristics or comorbid conditions influenced any outcome category in this analysis to any clinically important degree greater than FIM motor admission score, age, and walking distance. Though regional and racial differences in outcomes have been identified using this data set,24,25 neither geographical region or racial category contributed to prediction of primary outcomes of interest in this sample, including only individuals who were previously living at home and admitted for an initial rehabilitation stay directly from an acute hospital setting.

The strength of this primary measure of functional performance in predicting inpatient rehabilitation outcome again supports the use of FIM scoring in determining reimbursement categories for inpatient rehabilitation after stroke.26–28 This analysis addresses many concerns about previous reports of outcome prediction after stroke related to the importance of involving multiple centers and representative samples, adequate sample size, and inclusion of comprehensive and validly measured clinical predictive and outcome variables.7,29–31 This analysis also used a representative sample of individuals hospitalized after stroke for rehabilitation after the Centers for Medicare & Medicaid Services implemented the IRF prospective payment system in January 2002.32

Although FIM score dominates outcome prediction in this analysis for the average effect, with low P values and confidence limits indicating its precision, the wide range of scores was the inclusion of a broad range of clinical characteristics and stroke-related comorbid conditions that have previously been shown to be important in predicting outcomes (eg, urinary incontinence, stroke mechanism, social support, marital status, lesion hemisphere, and dysphagia). The UDSMR data set provided powerful analytic opportunities to demonstrate that none of these clinical characteristics or comorbid conditions influenced any outcome category in this analysis to any clinically important degree greater than FIM motor admission score, age, and walking distance. Though regional and racial differences in outcomes have been identified using this data set,24,25 neither geographical region or racial category contributed to prediction of primary outcomes of interest in this sample, including only individuals who were previously living at home and admitted for an initial rehabilitation stay directly from an acute hospital setting.

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Although FIM score dominates outcome prediction in this analysis for the average effect, with low P values and confidence limits indicating its precision, the wide range of scores

Table 3. Discharge Outcomes

<table>
<thead>
<tr>
<th>Discharge location</th>
<th>Overall (n=148,367)</th>
<th>Ischemic (n=144,266)</th>
<th>Hemorrhagic (n=4,101)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home (%)</td>
<td>27,915 (19)</td>
<td>27,273 (19)</td>
<td>642 (16)</td>
</tr>
<tr>
<td>Skilled nursing</td>
<td>193 (0.1)</td>
<td>193 (0.1)</td>
<td>0</td>
</tr>
<tr>
<td>Long-term care</td>
<td>14,819 (10)</td>
<td>14,253 (10)</td>
<td>566 (14)</td>
</tr>
<tr>
<td>Acute hospital</td>
<td>244 (0.2)</td>
<td>231 (0.2)</td>
<td>13 (0.3)</td>
</tr>
<tr>
<td>Died</td>
<td>998 (0.7)</td>
<td>960 (0.7)</td>
<td>38 (0.9)</td>
</tr>
</tbody>
</table>

FIM indicates functional independence measure.

*Change in FIM score/length of stay.
at admission that are associated with favorable outcome in each category may indicate that other factors not considered here are influential (e.g., education and socioeconomic status). This variation also makes outcome prediction for a specific individual imprecise, as reflected in the final model’s $r^2$ value of 0.107.

These results also emphasize that clinical characteristics previously reported as predictive of outcome after stroke (lesion hemisphere, stroke mechanism, and urinary incontinence) may be considered less important when assessing the indication for inpatient rehabilitation in the acute phase after stroke.

Figure 1. Three-variable (admission functional independence measure [FIM] motor subscore, age, and walking distance) fit for the outcome FIM gain. Solid lines indicate ischemic stroke, and hatched lines indicate hemorrhagic stroke. Vertical lines extending upward from the x-axis indicate the 10th, 25th, 50th, 75th, and 90th percentiles of the predictor variables.

Figure 2. Three-variable (admission functional independence measure [FIM] motor subscore, age, and walking distance) fit for the outcome length of stay. Solid lines indicate ischemic stroke, and hatched lines indicate hemorrhagic stroke. Vertical lines extending upward from the x-axis indicate the 10th, 25th, 50th, 75th, and 90th percentiles of the predictor variables.
This study has limitations. It was a retrospective analysis of data collected for clinical reasons, practice improvement, and for comparison between practice settings. Data quality is dependent on the skill and consistency of the individual clinicians at each site contributing it. However, each facility is certified every 2 years by standardized testing that strengthens the reliability of the FIM ratings. Clinical information included in the UDSMR data set has been shown to have excellent reliability. Because a cost is associated with participation in the UDSMR, this may affect the representativeness of contributing institutions and the sample used in this analysis. However, the UDSMR database represents >70% of the IRF market share in the United States. These findings pertain only to outcome prediction at rehabilitation hospital discharge and may not be relevant for more ethnically diverse specific regions of the United States or other countries. Future analysis is planned to study prediction of outcome after stroke in the postacute phase.

Conclusions
This analysis shows that age and a measure of functional independence at rehabilitation hospital admission for stroke are the predominant predictors of outcome at discharge in a uniquely large US national data set. Other clinical factors previously reported to be strong predictors of outcome after stroke (eg, preexisting medical and stroke-related comorbid conditions) did not substantially contribute to this prediction. Although this model lacks precision for predicting outcome for specific individuals, when these predictor variables are considered together with key clinical information not included in this data set, they can inform medical decision making when assessing rehabilitation service needs in the acute hospital, particularly when disposition planning is complex and challenging. The primary importance of motor performance in predicting outcomes can also focus clinical plans of care for individuals at rehabilitation hospital admission to enhance opportunities for returning home.

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Disclosures
Drs Niewczyk and Granger are employed by Uniform Data System for Medical Rehabilitation. Dr Granger was one of the developers of the FIM instrument. The other authors have no conflicts to report. FIM is a trademark of Uniform Data System for Medical Rehabilitation, a division of UB Foundation Activities, Inc.

References


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Printed Name: [Name]
Signature: [Signature]
Date: [Date]

Printed Name: [Name]
Signature: [Signature]
Date: [Date]

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