Does comorbidity affect the outcome of surgery? Total hip replacement in the UK and Japan

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Abstract

Objectives. To assess the impact of comorbidity on the outcome of surgery in the UK and in Japan; to determine the predictive ability of a new measure of comorbidity, the Index of Co-Existent Diseases (ICED); and to see if its predictive power could be improved.

Design. Logistic regression using data from two retrospective cohorts with prospective outcome data collection.

Setting. Six hospitals (three teaching, three non-teaching) in the UK and 15 (12 teaching, three non-teaching) hospitals in Japan.

Study participants. Patients undergoing total hip replacement (THR) surgery in the UK (n = 268) and in Japan (n = 249).

Main outcome measures. Serious complications before hospital discharge and change in three measures of general health status [basic activities of daily living (ADL); instrumental ADL; social activities].

Results. The distribution of levels of comorbidity differed between the UK and Japan: none (26.1 versus 42.2%); mild (30.6 versus 43.0%); moderate (23.5 versus 12.0%); and severe (19.8 versus 2.8%). In the UK, the incidence of serious complications was higher in patients with moderate (27.0%) or severe (26.4%) comorbidity than in those with no (14.3%) or mild (13.4%) comorbidity (P<0.001). In contrast, no significant association was found in Japan. The relationship between comorbidity and change in health status was weak in the UK and non-significant in Japan. Logistic regression confirmed that comorbidity was a significant predictor of serious complications in the UK. The only other significant factor was surgical approach (anterior/antero-lateral; odds ratio 2.16, P<0.05). Attempts to improve the predictive power of the ICED by modifying its structure and by reclassifying complications was successful in achieving a linear (rather than dichotomous) relationship. The predictive power, however, was poor.

Conclusions. Comorbidity is a significant determinant of serious complications following THR but not of changes in functional or health status. Comparisons of clinical performance using post-operative complications must take levels of comorbidity into account if they are to be meaningful. The ICED is of less validity in the UK and Japan than in its country of origin, the USA. Further work to develop better instruments for the UK and Japan is needed.

Keywords: comorbidity, complications, total hip replacement

As the demand for health services to be accountable has grown, methods of risk adjustment have been developed to allow more meaningful comparisons of performance to be made. While much effort has been devoted to developing methods to measure the severity of principal conditions, the measurement of co-existent or comorbid conditions has been relatively neglected [1]. Despite this, the potential importance of comorbidity as a determinant of outcome and resource use has been recognized [2–6]. Initial attempts to measure comorbidity involved a simple dichotomy (present or absent) without considering severity. Kaplan and Feinstein were the first to define and classify comorbidity according to severity [7, 8] and this classification was extended later by Charlson who adopted different weightings among comorbidities [9].
More recently, Greenfield and colleagues have developed the Index of Co-Existing Disease (ICED) which includes the severity of functional impairment in addition to that of physical impairment [10]. The index was developed (on a theoretical rather than empirical basis) for a retrospective cohort study in which the care systems in six US hospitals were compared [11]. Subsequently, using the ICED in Italy, it was found that comorbidity was a powerful independent prognostic factor in determining mortality of patients with end-stage renal disease [12]. Another study on 69 patients receiving peritoneal dialysis also supported this finding and suggested the ICED was more informative than simple enumeration of comorbid conditions [13]. The ICED has also been used to explore the relationship between casemix and hospital readmission [14]. Its developers envisaged it being applied to retrospective data obtained through chart or medical record review. The test-retest reliability of the ICED has been shown to be excellent and the inter-rater reliability has been shown to be moderate [15].

The primary objective of this study was to assess the impact of comorbidity on the outcome of a common surgical procedure. It was hypothesized that comorbidity would affect the incidence of complications but not improvements in health status. The secondary objective was to test the validity of the ICED in two countries where it had not previously been used, Japan and the UK. Attempts were also made to improve the predictive ability of the ICED.

Patients undergoing total hip replacement (THR) were selected because it is a common procedure, most patients are elderly and suffer from comorbid conditions, and a previous study in the UK on the appropriate indications for THR had revealed variations among surgeons in their views of the importance of the presence or absence of different levels of comorbidity [16].

**Methods**

**Study design**

Two retrospective cohorts of patients over the age of 18 years who had undergone a primary THR were identified, one in Japan and one in the UK. The cohort in Japan were drawn from 15 hospitals (12 teaching and three non-teaching). Inclusion of hospitals was based entirely on those in which the head of orthopaedic surgery gave his agreement. Consecutive patients who had been treated between 9 and 15 months earlier (April–December 1992) were invited to participate. The cohort in the UK was made up of consecutive cases treated between September 1992 and October 1993 in six hospitals (three teaching and three non-teaching). Cases were excluded if: the operation was a revision procedure or was bilateral during one theatre episode; a diagnosis had been made of Paget’s disease, femoral fracture, AIDS or metastatic cancer; the patient was receiving chemotherapy or was a transplant patient. Eligible patients consenting to participate were mailed a self-administered questionnaire and their permission was sought to abstract data from their case notes using a standard form designed for the study. Published data from a cohort of THR patients in the USA were used to make comparisons [10].

**Case note abstraction**

Case notes provided information about patients’ age, sex, comorbidity, any past history of hip surgery, anaesthesia, surgical approach, hospital, use of blood transfusions, use of cement, and serious post-operative in-hospital complications. The latter included hypotension, neuroopathy, thrombembolic events, septicaemia, cardiac arrest, myocardial infarction, respiratory failure, and renal failure.

Comorbidity was defined as the overall severity of illness due to diseases other than hip disease that could affect recovery from surgery. It was measured using ICED, an index made up of two subindices – an index of disease severity and a functional severity index [10] (see Appendix). The former grades the severity of 13 disease categories from level 0 (none) to level 3 (severe). Functional severity was determined by assessment of 10 functions each classified into three levels from level 0 (normal function) to level 2 (severe limitation). The peak score of any category within each subindex represented the severity of that subindex. Finally the scores of the two subindices were combined to assign an overall level of severity of comorbidity, from level 1 (none) to level 4 (severe).

**Patient questionnaires**

The mailed questionnaires were sent to patients approximately 12 months after surgery and enquired about their sociodemographic characteristics (marital status, education, living alone, housing tenure), limp, use of walking aids, and general health status during the month before surgery and during the last month. General health status was based on three scales: three questions on basic activities of daily living (ADL) (which covered eating, dressing and bathing), six questions on instrumental ADL (such as doing light work around the house, walking several blocks, and doing vigorous activities), and three questions on social activities (visiting friends, participating in community activities, and taking care of family members). Each item was scored from 0 (poor status) to 4 (good status). Scores for each scale were averaged and transformed to the range of 0–100, with a score of 100 indicating the best possible health status. The acceptability, reliability and construct validity of the patient questionnaire have been shown to be good [17]. The Japanese version of the questionnaire was developed by translating the original US version, then back-translating it and correcting any changes of meaning that had been introduced.

**Data analysis**

The statistical significance of differences were determined using t-tests for means, $\chi^2$ tests for proportions, and Mann–Whitney U tests for the mean rank of groups for categorical variables. The relationships between ICED and outcomes were assessed using $\chi^2$ for trend (complications) and Kruskal–Wallis tests (change in health status).
Confounding was explored by means of logistic regression models using forward stepwise selection with a likelihood criterion of \( P<0.05 \). The adequacies of these models were examined using residual analysis as a diagnostic statistic.

**Results**

**Recruitment and response**

Of the 300 eligible patients in Japan, 256 (85.3%) agreed to participate by returning completed questionnaires. The case notes of 249 (97% of participants) were found and were complete. In the UK, 301 of 373 eligible patients returned completed questionnaires (80.7%). Retrieval of complete case notes was achieved for 268 (89% of participants). The availability of data in the case notes was generally similar in Japan and the UK, with the exceptions of information on living alone or not (100 versus 78%) and surgical approach (68 versus 93%).

Some patients failed to answer some of the questions in the mailed questionnaire for a variety of reasons: there were too many questions; difficulty in determining the contribution of hip disease to their general health problems; and failure to perceive any apparent relevance to their hip problems. In general, there were only low levels (<5%) of missing data among those responding.

**Comorbidity**

In both countries, the distribution of patients classified by the index of disease severity subindex was biphasic: there were fewer patients at Level 1 than at Level 0 or 2 (Table 1). The ICED scores were closer to a normal distribution in the UK than in Japan, where the majority of patients were either Level 1 or 2. A striking difference was observed in the proportions of patients at Level 3 or 4: 14.8% in Japan compared with 43.3% in the UK.

**Sociodemographic, medical and treatment characteristics**

The two cohorts differed in all sociodemographic and medical characteristics, with the exception of previous surgery on the same hip (Table 2). Japanese patients were more likely to be younger, female, married, living with others, owning their own home, and completing their education later. They had less severe hip disease as assessed by the extent of limping and their need for walking aids.

The patterns of treatment of hip disease differed: operations in Japan were more likely to be conducted under general anaesthesia, to involve an anterior or antero-lateral approach, to make use of blood transfusion, and to be cement free. These differences have been reported in greater detail elsewhere [18].

**Relationship between comorbidity and serious complications**

The relationship between the risk of a serious complication and ICED level in Japan and in the UK differed from the significant, exponential relationship previously demonstrated in the USA (Table 3 and Figure 1). In Japan only 4.4% of patients experienced a serious complication and no significant trend with ICED was found. Low rates of complications occurred at Levels 1–3 with a rate four times higher in Level 4 patients, suggesting a threshold effect. Serious complications were more commonly reported in the UK, with a significant trend evident with a dichotomized pattern in which moderate complication rates in Levels 1 and 2 were similar (about 14%) as were the rates in Levels 3 and 4 (about 27%) (\( \chi^2 \) for trend = 4.2; \( P<0.05 \)). In contrast, the rate rose from 3%
Table 2 Comparison of patients' sociodemographic, medical and treatment characteristics between Japan (n = 249) and the UK (n = 268)

|                          | Japan (n = 249) | UK (n = 268) | P-value  |
|--------------------------|----------------|--------------|----------|
| Mean age (years) ± SD    | 60 ± 10        | 68 ± 12      | <0.0001  |
| Female                   | 217 (84.8)     | 193 (64.1)   | <0.0001  |
| Married                  | 188 (77.0)     | 173 (58.4)   | <0.0001  |
| Living alone             | 28 (11.4)      | 102 (34.8)   | <0.0001  |
| House ownership          | 208 (84.6)     | 191 (64.5)   | <0.0001  |
| Age completed education (years) |          |              |          |
| 15 or less               | 52 (21.4)      | 179 (61.9)   | <0.0001  |
| 16–18                    | 159 (65.7)     | 68 (23.5)    |          |
| 19 or more               | 32 (12.9)      | 42 (14.5)    |          |
| Prior hip surgery (either side) |          |              |          |
| On same hip              | 15 (6.0)       | 16 (6.0)     | 0.9794   |
| On other hip             | 43 (17.3)      | 68 (25.4)    | 0.0249   |
| THR on other hip         | 31 (12.4)      | 60 (22.4)    | 0.0030   |
| Severity of limp         |                |              |          |
| None                     | 5 (4.9)        | 8 (3.1)      | <0.0001  |
| Slight                   | 62 (25.2)      | 22 (9.5)     |          |
| Moderate                 | 111 (45.1)     | 78 (28.8)    |          |
| Severe                   | 47 (19.1)      | 137 (51.2)   |          |
| Unable to walk           | 18 (7.3)       | 18 (7.5)     |          |
| Missing                  | 3              | 5            |          |
| Walking aids             |                |              |          |
| None (or rarely)         | 88 (36.4)      | 71 (25.3)    | <0.0001  |
| Single cane or crutch    | 120 (49.6)     | 122 (45.8)   |          |
| Two canes or crutch      | 19 (7.9)       | 44 (18.2)    |          |
| Walker                   | 6 (2.5)        | 6 (3.0)      |          |
| Wheelchair               | 9 (3.7)        | 23 (7.7)     |          |
| Missing                  | 7              | 2            |          |
| General anaesthesia      | 200 (80.3)     | 260 (97.0)   | <0.0001  |
| Surgical approach (anterior/ anterolateral) | 86 (30.4) | 60 (24.2) | <0.0001 |
| Transfusion              | 238 (96.0)     | 208 (77.6)   | <0.0001  |
| Cemented prosthesis      | 101 (40.6)     | 232 (88.5)   | <0.0001  |

Probability based on: 1 \(t\)-test; 2 \(\chi^2\) test; 3 Mann–Whitney U test.

THR, Total hip replacement.

in Level 1 to 41% in Level 4 in the USA (\(\chi^2\) for trend = 22.6; \(P<0.001\)).

Relationship between comorbidity and change in health status

Figure 2 shows the relationship between change in each of the three dimensions of health status and the ICED. Interpretation of the Japanese data was limited by the large standard error for Level 4 of the ICED, which included only seven patients. No statistically significant association was found between comorbidity and any dimension of health status.

A weak dichotomous pattern was observed again in the UK, particularly for instrumental ADL. Patients with low levels of pre-operative comorbidity experienced slightly
Table 3 Frequency distribution of patients with serious complications for the two subindices (index of disease severity and functional severity) and for the ICED in Japan, the UK and the USA

| Index                  | Level of index | Japan | UK    | USA    |
|------------------------|----------------|-------|-------|--------|
| Index of disease       | 0              | 7     | 10 (13.7) | 4 (3.8) |
|                        | 1              | 0     | 7 (19.4) | 7 (10.2) |
|                        | 2              | 2     | 21 (18.1) | 23 (13.2) |
|                        | 3              | 2     | 14 (32.6) | 4 (36.4) |
| Functional severity    | 0              | 11 (5.4) | 26 (16.0) | 14 (6.6) |
|                        | 1              | 0     | 24 (25.8) | 19 (14.4) |
|                        | 2              | 0     | 2 (15.4) | 5 (50.8) |
| Index of co-existent disease (ICED) | 1 | 7 (6.7) | 10 (14.3) | 3 (2.9) |
|                        | 2              | 2     | 11 (13.4) | 11 (8.4) |
|                        | 3              | 0     | 17 (27.0) | 17 (16.3) |
|                        | 4              | 2     | 14 (26.4) | 7 (41.2) |

1 $P<0.05$ based on $\chi^2$ test for trend.

Figure 1 Serious complication rates (95% CI) by ICED level in Japan, UK and USA

greater improvement in their health status. This association was statistically significant for basic ADL ($P=0.035$) and instrumental ADL ($P=0.038$) but not for social activity ($P=0.055$). Given these relatively small differences, further predictive analyses were limited to in-hospital complications as the outcome.

Figure 2 Change in mean ($\pm$ SE) measure of health status in Japan and the UK.
linear. To see if that could be achieved, the classification of the ICED was examined, the distributions were not normal, suggesting that the models did not fit the data well and thus the model prediction level was a poor predictor of complications.

### Prediction of serious complications by comorbidity

In order to see which patient variables were confounding the effect of comorbidity on the rate of serious in-hospital complications, several factors suggested by previously published studies were considered as potential confounders: sociodemographic (age, sex, living alone, marital status, education level, housing tenure); severity of hip disease (past history of hip surgery, limp, use of walking aids); and clinical management (anaesthesia, amount of transfusion, cement use, surgical approach, hospital).

Potential predictors were examined by forward stepwise selection in a logistic regression model. In Japan, none of these factors were found to be significantly associated with the occurrence of serious complications, whereas in the UK, two were. The complication rate following an anterior/antero-lateral approach was 30.0% [95% confidence interval (CI) 19.2-43.4] compared with 16.5% [95% CI 11.6-22.8] following other approaches (p=0.022). Complication rates also varied by hospital from 10.9% [95% CI 4.9-21.8] to 36.8% [95% CI 17.2-61.4] (p=0.013).

Each level of the ICED was treated as a dummy variable, using Level 1 as a reference category. Table 4 shows the regression estimates of the logistic model in which higher levels of the ICED were significant predictors of serious complications. Odds ratios for ICED Levels 3 and 4 were similar, reflecting the dichotomous nature of the measure of comorbidity. Surgical approach was also a significant variable, with similar predictive power to the higher levels of the ICED. Hospital was no longer significant, suggesting that the difference in complication rates between hospitals was related to differences in the surgical approach adopted and level of comorbidity. When the normal probability of the deviances was examined, the distributions were not normal, suggesting that the models did not fit the data well and thus the model was a poor predictor of complications.

### Attempts to improve the power of the ICED to predict serious complications

Ideally the ICED–complication rate relationship would be linear. To see if that could be achieved, the classification of serious complications was first reviewed. The exclusion of dislocation and the inclusion of neuropathy in the original US study were deemed to be clinically questionable, so these decisions were reversed. These changes reduced the number of patients with a serious complication from 11 to five in Japan and from 52 to 48 in the UK (Table 5). As a result, the complication rate became significantly associated with the ICED in Japan and the level of statistical significance in the UK increased slightly. The previously observed threshold effect in Japan was enhanced due to a reduction in the complication rate in ICED Level 1 (Figure 3). In the UK, the dichotomous pattern was modified into a more S-shaped curve.

In order to see how such a change in outcome criteria might effect the predictive power of the ICED, a logistic model was developed. Higher levels of ICED were significant independent variables in the UK with increasing odds ratios (Table 6). Although surgical approach had been found to be a significant independent predictor with the ICED, it was no longer significant using the newly defined outcome.

Second, the composition of the ICED was reviewed. The lack of an association between the functional severity subindex and serious complications (Table 3) meant that attempts to improve the predictive power had to focus on the index of disease severity (IDS). As the severity level of each disease category had been determined at the time of abstracting data from patients’ medical records, reclassification would only have been possible by repeating all the data collection. Modification of the ICED had, therefore, to concentrate on changing the disease categories included in the IDS. Those categories which were most predictive of serious complications, irrespective of their severity, were identified. These were then used to form a new ICED. Statistically significant associations were observed with peripheral vascular disease in Japan, and primary arrhythmias and conduction problems, congestive heart failure, and hepatobiliary disease in the UK. Because only one patient suffered from peripheral vascular disease in the Japanese cohort, further analyses were limited to the UK data.

Using the three significantly associated disease categories, a final severity score was derived from the peak intensity curve.
Table 5 Frequency distribution of patients with a serious complication by ICED in Japan and the UK using the original and the new criteria for defining complications

| Criteria of serious complication | ICED level | Japan (n=249) | UK (n=268) |
|---------------------------------|------------|--------------|------------|
| Original                        |            |              |            |
| 1                               | 7 (6.7)    | 10 (14.3)    |
| 2                               | 2 (1.9)    | 11 (13.4)    |
| 3                               | 0 (0.0)    | 17 (27.0)    |
| 4                               | 2 (28.6)   | 14 (26.4)    |
| $\chi^2$ for trend (df = 1)     | 0.941      | 4.185        |
| $P$-value                       | NS         | <0.05        |

| New                             |            |              |            |
| 1                               | 1 (1.0)    | 7 (10.0)     |
| 2                               | 2 (1.9)    | 11 (13.4)    |
| 3                               | 0 (0.0)    | 16 (25.4)    |
| 4                               | 2 (28.6)   | 14 (26.4)    |
| $\chi^2$ for trend (df = 1)     | 13.467     | 6.601        |
| $P$-value                       | <0.001     | <0.05        |

df, degree of freedom; NS, not significant.

This new index was found to be more significantly associated with serious complications than the original ICED (Table 7). The new index also changed the dichotomous pattern previously observed (Figure 1) into more of a linear relationship, though the wide confidence intervals preclude any firm conclusion (Figure 4). A similar association was observed when the new ICED was applied to serious complications defined using the new criteria (data not shown).

Finally, the predictive ability of the new ICED was examined, taking Level 1 as the reference (Table 8). Level 3 was a significant independent predictor of serious complications using either the original or the new criteria, whereas surgical approach was no longer significant using the new criteria. Using the new criteria, both Levels 2 and 3 were significant predictors. However, the predictive power was poor. Only five complications out of the 49 that occurred in the UK patients were predicted using the original criteria, and none when using the new criteria.

Discussion

Clinical and health services research and audit have rarely taken comorbidity into account when evaluating the effectiveness of health care interventions. This is partly because of the lack of a validated, practical method for measuring comorbidity and partly a lack of concern for the impact coexistent diseases might have on the outcome of care. This study has confirmed previous work in other countries, most notably the USA, in demonstrating that comorbidity is an important and significant determinant of serious complications but has little influence on the extent of change in the health status of patients.
Table 6 Prediction of serious complications (new criteria) by the ICED in the UK ($n=248$)

| Variable                | Unstandardized regression estimates | Standard error of estimate | Odds ratio (95% confidence interval) | $P$-value |
|-------------------------|-------------------------------------|---------------------------|--------------------------------------|-----------|
| Constant                | $-2.36$                             | $0.44$                    |                                      | NS        |
| ICED level 2            | $0.31$                              | $0.55$                    | $1.37$ (0.47–4.01)                   | NS        |
| ICED level 3            | $1.20$                              | $0.52$                    | $3.31$ (1.19–9.21)                   | $<0.05$   |
| ICED level 4            | $1.35$                              | $0.54$                    | $3.87$ (1.35–11.00)                  | $<0.05$   |
| Anterior approach       | $0.50$                              | $0.37$                    | $1.65$ (0.80–3.38)                   | NS        |

NS, not significant.

Table 7 Frequency distribution of patients with serious complications defined by the original ICED and the new ICED, in the UK ($n=248$)

| Index                  | Levels of index | Number of patients | Number (%) of patients with complication | $\chi^2$ for trend | $P$-value |
|------------------------|-----------------|--------------------|------------------------------------------|--------------------|-----------|
| Original ICED          | 1               | 70                 | 10 (14.3)                                | 4.2                | $<0.05$   |
|                        | 2               | 82                 | 11 (13.4)                                |                    |           |
|                        | 3               | 63                 | 17 (27.0)                                |                    |           |
|                        | 4               | 53                 | 14 (26.4)                                |                    |           |
| New ICED               | 1               | 171                | 22 (12.9)                                | 12.8               | $<0.001$  |
|                        | 2               | 43                 | 11 (25.6)                                |                    |           |
|                        | 3               | 54                 | 19 (35.2)                                |                    |           |

Figure 4 Relationship of serious complication and comorbidity index (UK) (mean ± 95% CI)

In the UK (assuming our sample was representative of typical patients and clinical practice), patients with moderate or severe comorbidity were two and a half times as likely to suffer a serious complication following total hip replacement as those with no or only mild comorbidity. While an association was found in Japan, it was only patients with severe comorbidity who were at increased risk and this did not reach statistical significance at the 5% level. These findings were in marked contrast to the exponential relationship demonstrated by the developers of the ICED in the USA, where patients with severe comorbidity were about 12 times as likely to experience a serious complication as those without co-existent diseases.

Attempts to improve the predictive power of comorbidity met with only limited success. Changes to the criteria of serious complications increased the odds ratio for patients in the UK with moderate comorbidity from about 2.5 to 3.3 and for those with severe comorbidity to 3.9. It also shifted the relationship from a clearly dichotomized one closer to an S-shaped curve, although it is still very different from the exponential curve found in the USA. Meanwhile, in Japan the change in criteria of complications led to the previously observed relationship reaching statistical significance.

Redefining the composition of the ICED had a marked impact on the association with complications. A linear relationship resulted, in which the odds ratio for patients with moderate or severe comorbidity (not distinguished from one another in the new ICED) was 4.4. This improvement was, however, achieved at the expense of the predictive power of the new instrument.

Why might the predictive ability of the ICED in the UK and in Japan have been so different from that reported previously from the USA [10]? The methods of selecting the patient cohorts was similar and we have no reason to believe...
Japanese surgeons may take greater responsibility in detecting co-existent diseases. In Japan, a patient’s pre-operative length of stay is much shorter than in Japan and fewer investigations are performed than in the USA. Also, although in the UK in theory information on co-existent diseases should be communicated by the patient’s general practitioner to the surgeon, this does not always happen. In contrast, Japanese surgeons may take greater responsibility in determining all the patient’s health problems rather than relying on information from a referring doctor.

Second, data on complications may differ systematically between countries. While it is possible that doctors varied in their observation and recording of complications, this seems an unlikely explanation as the study was restricted to serious events. The only complications that might conceivably have been under-reported were hypotension (blood pressure below 90/60 at any point during hospitalization) and neuropathy. Detection of a fall in blood pressure might be dependent on the frequency with which it was checked routinely. Such routines might differ between countries. A more likely explanation for the difference in hypotension rates between Japan (0.8%), the USA (3.4%) and the UK (12.3%) is the more prolonged routine use of post-operative parenteral fluids in Japan and the USA. Neuropathy seems an unlikely candidate for explaining the overall differences in complication rates as there was little difference in the rate of neuropathy between the three countries.

Third, it is possible that comorbidity factors, other than those covered by the ICED, were present in the UK and Japan but absent in the USA. In other words, the ICED did not reflect accurately the burden of a patient’s comorbidity level in Japan and the UK. Some evidence for this can be seen in the large regression estimate for the constant in the regression model.

Fourth, the comparative lack of comorbidity among the Japanese patients might have tested the ICED beyond the range in which it can successfully operate. Less than 15% of Japanese patients had moderate or severe comorbidity compared with over 40% in the UK and almost 35% in the USA.

Clearly, further research and development are needed in the UK and in Japan before the ICED can make a worthwhile contribution. This could take several forms. First, the importance of how outcomes are defined was apparent from the effects seen when the criteria of serious complications were changed. Careful attention needs to be paid to defining outcome criteria. For example, one crucial outcome that was ignored in this study was death (although including the few deaths that occurred during the 12 month post-operative period as ‘serious complications’ made little difference to the results). Second, standardized methods of defining and recording comorbidity prospectively are needed. Third, while modification of the ICED is one way forward, it may be more productive outside the USA to try creating a new instrument by modelling raw data. And fourth, when any modified or new instrument has been developed, it needs to be tested prospectively in a variety of patient populations.

Finally, while the need for a validated measure of comorbidity for influencing clinical decisions, for auditing clinical performance, and for refining the purchasing of health care is beyond doubt, how much effort is it reasonable to expend on accurate measurement of co-existent diseases? A compromise has to be struck between, on the one hand, cost in terms of clinicians’ time and data collection and, on the other hand, accuracy. While no systematic attempt was made to compare the ICED with other measures of comorbidity in this study, it was possible to compare it to the American Society of Anaesthesiologists’ physical status (ASA-PS) grades in Japan. (This was not possible in the UK where this measure was recorded in only 41% of cases.) ICED levels were associated with ASA-PS grades (Spearman–Rank correlation

| Criteria of serious complication | Unstandardized regression estimates | Standard error of estimate | Odds ratio (95% confidence interval) | P-value |
|---------------------------------|------------------------------------|----------------------------|-------------------------------------|---------|
| Original criteria               |                                    |                            |                                     |         |
| Constant                        | -2.21                              | 0.28                       | 2.29 (0.95–5.49)                    | NS      |
| Level 2                         | 0.83                               | 0.45                       | 4.43 (2.08–9.43)                    | <0.0005 |
| Level 3                         | 1.49                               | 0.39                       | 2.47 (1.21–5.04)                    | <0.05   |
| Anterior approach               | 0.90                               | 0.36                       |                                     |         |
| New criteria                    |                                    |                            |                                     |         |
| Constant                        | -2.29                              | 0.29                       | 3.21 (1.34–7.67)                    | <0.01   |
| Level 2                         | 1.17                               | 0.44                       | 4.67 (2.16–10.10)                   | <0.0005 |
| Level 3                         | 1.54                               | 0.39                       |                                     |         |
| Anterior approach               | 0.61                               | 0.38                       | 1.83 (0.87–3.85)                    | NS      |

NS, not significant.
coefficient 0.6421; \( P<0.0001 \) but as with the ICED, the trend in serious complication rate by ASA-PS grade was not significant. Given that ASA-PS grading is routinely available in many hospitals, any new measure must outperform it sufficiently to make the extra effort worthwhile.

References

1. Iezzoni L. (ed.) Risk Adjustment for Measuring Health Care Outcomes. Ann Arbor, MI: Health Administration Press, 1994.
2. Hart LG, Evans RW. The functional status of ESRD patients as measured by the sickness impact profile. J Chron Dis 1987; 40: S117–S130.
3. Greenfield S, Aronow HU, Elashoff RM, Watanabe D. Flaws in mortality data. J Am Med Assoc 1988; 5: 2253–2255.
4. Pompei P, Charlson ME, Douglas G. Clinical assessments as predictors of one year survival after hospitalization: implications for prognostic stratification. J Clin Epidemiol 1988; 41: 275–284.
5. Naessens JM, Leibson CL, Krishan I, Ballard DJ. Contribution of a measure of disease complexity (COMPLEX) to prediction of outcome and charges among hospitalized patients. Mayo Clin Proc 1992; 67: 1140–1149.
6. Concato J, Horwitz RI, Feinstein AR et al. Problems of morbidity and mortality after prostatectomy. J Am Med Assoc 1992; 267: 1077–1082.
7. Feinstein AR. The pre-therapeutic classification of co-morbidity in chronic disease. J Chron Dis 1970; 23: 455–468.
8. Kaplan MH, Feinstein AR. The importance of classifying initial co-morbidity in evaluating the outcome of diabetes mellitus. J Chron Dis 1974; 27: 387–404.
9. Charlson MD, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chron Dis 1987; 40: 373–383.
10. Greenfield S, Apolone G, McNeil BJ, Cleary PD. The importance of co-existent disease in the occurrence of postoperative complications and one-year recovery in patients undergoing total hip replacement. Med Care 1993; 31: 141–154.
11. Cleary PD, Greenfield S, Mulley AG et al. Variations in length of stay and outcomes for six medical and surgical conditions in Massachusetts and California. J Am Med Assoc 1991; 266: 73–79.
12. Nicolucci A, Cubasso D, Labrozzi D et al. Effects of coexistent diseases on survival of patients undergoing dialysis. AHA J 1992; M291–M295.
13. Athienitis NV, Sullivan L, Fernandez G et al. Pretreatment comorbidity and patient outcomes in peritoneal dialysis. 27th Annual Meeting of American Society of Nephrology, 1994 (abstract).
14. Wire K, Oddone E, Weiberger M et al. Lack of association between patients’ measured burden of disease and risk for hospital readmission. J Clin Epidemiol 1994; 47: 1229–1236.
15. Imamura K, McKinnon M, Middleton R, Black N. Reliability of a comorbidity measure: the Index of Co-Existent Disease (ICED). J Clin Epidemiol 1997; 50: 1011–1016.
16. Imamura K, Gair R, McKee M, Black N. Appropriateness of total hip replacement in the United Kingdom. World Health Stat Q 1996; 32: 10–14.
17. Cleary PD, Reilly DT, Greenfield S et al. Using patient reports to assess health-related quality of life after total hip replacement. Qual Life Res 1993; 2: 3–11.
18. Imamura K, Black NA. Total hip replacement: the pre-operative health status of patients in Japan compared with England and the USA. Int J Tech Assess Health Care 1997; 13: 1–10.

Appendix

Index of co-existent disease

(1) Index of disease severity (IDS)

The severity of each of 13 disease categories is classified into one of four grades. The categories are rated using an explicit list of symptoms, signs and laboratory tests.

Grade 0 Absence of coexistent disease

Grade 1 A comorbid condition which is asymptomatic or mildly symptomatic where there is little or no comorbidity

Grade 2 A mild to moderate condition that is generally symptomatic and requires medical intervention. This also includes past conditions, presently benign, that still present a moderate risk of morbidity

Grade 3 An uncontrolled condition which causes moderate to severe disease manifestations during medical care. These conditions are usually acute or subactive and require medical intervention.

The 13 categories are: organic heart disease (OHD); ischemic heart disease (IHD); primary arrhythmias and conduction problems; congestive heart failure (no known IHD or OHD); hypertension; cerebral vascular accident; peripheral vascular disease; diabetes mellitus; respiratory problems; malignancies (excluding basal cell carcinomas of the skin); hepatobiliary disease; renal disease; and gastro-intestinal disease.

If only one disease has been identified the patient’s IDS level will correspond to the grade of that item. When more than one co-existent disease exists, a patient is placed in the level corresponding to the highest item grade (peak severity of coexistent diseases). The IDS levels reflect the maximum severity of any coexistent disease:

Level 0 No history or evidence of coexistent disease

Level 1 Asymptomatic controlled disease

Level 2 Symptomatic controlled disease

Level 3 Uncontrolled disease
(2) Functional severity (FS)
This component is intended to act as a snapshot of the impact of all the conditions, diagnosed or not, on the patient’s functional status. Ten body systems are assessed using explicit criteria and the degree of impairment of each system is classified in one of three levels.

- **Level 0** No significant impairment/normal function
- **Level 1** Mild or moderate impairment. Selection of level 1 must be based on documentation
- **Level 2** Serious/severe impairment. Selection of level 2 must be based on documentation.

The 10 system categories are: circulation; respiration; neurological; mental status; urinary; faecal; feeding; vision; hearing; and speech.

The FS level is determined by the highest score recorded in any of the 10 items:

- **Level 0** No major identified problem or impairment
- **Level 1** Mild or moderate impairment
- **Level 2** Severe/serious impairment

(3) The ICED
The two index scores are condensed into a single ICED score using four categories.

| Peak intensity of disease severity (0, 1, 2, 3) | Peak intensity of functional severity (0, 1, 2) | ICED levels (1, 2, 3, 4) |
|---------------------------------------------|---------------------------------------------|--------------------------|
| 0                                           | 0                                           | 1                        |
| 0                                           | 1                                           | 1                        |
| 1                                           | 0                                           | 2                        |
| 2                                           | 0                                           | 2                        |
| 1                                           | 1                                           | 3                        |
| 2                                           | 1                                           | 3                        |
| 3                                           | Any (0, 1 or 2)                              | 4                        |
| Any (0–3)                                   | 2                                           | 4                        |

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