One-Year Quality of Life Post–Pneumonia Diagnosis in Japanese Adults

Henry A. Glick,1,a Taiga Miyazaki,2,a Katsuji Hirano,2,a Elisa Gonzalez,4 Luis Jodar,4 Bradford D. Gessner,4 Raul E. Isturiz,4 Adriano Arguedas,4,a Shigeru Kohno,2 and Jose A. Suaya4

1Department of Medicine, Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA; 2Department of Respiratory Medicine, Nagasaki University Hospital, Nagasaki, Japan; 3Department of Infectious Diseases, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan, and 4Vaccines Medical Development and Scientific/Clinical Affairs, Pfizer Inc, Collegeville, Pennsylvania, USA

Background. Pneumonia is a common, serious illness in the elderly, with a poorly characterized long-term impact on health-related quality of life (HRQoL). The Japanese Goto Epidemiology Study is a prospective, active, population-based surveillance study of adults with X-ray/CT scan–confirmed community-onset pneumonia, assessing the HRQoL outcome quality-adjusted life-years (QALYs). We report QALY scores and losses among a subset of participants in this study.

Methods. QALYs were derived from responses to the Japanese version of the EuroQol-5D-5L health-state classification instrument at days 0, 7, 15, 30, 90, 180, and 365 after pneumonia diagnosis from participants enrolled from June 2017 to May 2018. We used patients as their own controls, calculating comparison QALYs by extrapolating EuroQol-5D-5L scores for day −30, accounting for mortality and changes in scores with age.

Results. Of 405 participants, 85% were aged ≥65 years, 58% were male, and 69% were hospitalized for clinically and radiologically confirmed pneumonia. Compliance with interviews by patients or proxies was 100%. Adjusted EuroQol-5D-5L scores were 0.759, 0.561, 0.702, and 0.689 at days −30, 0 (diagnosis), 180, and 365, respectively. Average scores at all time points remained below the average day −30 scores (P < .001). Pneumonia resulted in a 1-year adjusted loss of 0.13 QALYs (~47.5 quality-adjusted days) (P < .001).

Conclusions. Substantial QALY losses were observed among Japanese adults following pneumonia diagnosis, and scores had not returned to prediagnosis levels at 1 year postdiagnosis. QALY scores and cumulative losses were comparable to those in US adults with chronic heart failure, stroke, or renal failure.

Keywords. pneumococcal pneumonia; quality of life; quality-adjusted life years.

Pneumonia is a major cause of morbidity and mortality among older adults worldwide, including Japan [1]. Incidence and case fatality rates of pneumonia increase with age, being higher among individuals with chronic comorbidities [2]. In Japan, the annual incidence of community-onset pneumonia (COP) has been estimated at 1690 per 100 000 population aged 15 years or older, with estimates for adults 65–74, 75–84, and 65 years and older at 2460, 5290, and 7930 per 100 000 population aged 15 years or older, with estimates for adults ≥65 years, 58% were male, and 69% were hospitalized for clinically and radiologically confirmed pneumonia. Compliance with interviews by patients or proxies was 100%. Adjusted EuroQol-5D-5L scores were 0.759, 0.561, 0.702, and 0.689 at days −30, 0 (diagnosis), 180, and 365, respectively. Average scores at all time points remained below the average day −30 scores (P < .001). Pneumonia resulted in a 1-year adjusted loss of 0.13 QALYs (~47.5 quality-adjusted days) (P < .001).

While the clinical characteristics of pneumonia are well known, there has been less study of associated health-related quality of life (HRQoL) impacts. For cost-effectiveness analyses, HRQoL is usually measured in terms of quality-adjusted life-years (QALYs). This combination of length of survival and life quality is used to support estimation of the burden of illness and evaluation of the potential value of interventions [4, 5]. For example, substantial pneumonia burden in adults arises from vaccine-preventable Streptococcus pneumoniae [1, 6, 7], which imposes major morbidity, mortality, and health costs [8–10].

Dozens of cost-effectiveness analyses of adult pneumococcal vaccination programs have been published, yet the data underlying QALY estimates are generally weak. To address this knowledge gap, we assessed QALY scores and QALY decrements for 1 year following pneumonia diagnosis in adults as part of the Goto Island, Japan, Epidemiology Study.

METHODS

Goto Epidemiology Study

The Goto Epidemiology Study is an ongoing prospective, active-surveillance, population-based study of adults with COP in Goto City, Japan, that began in December 2015. Goto City,
located in the southwest part of Japan, has approximately 40,000 inhabitants, 85% of them aged 18 years or older.

As defined in Japan, COP includes patients with symptoms and signs of pneumonia with an onset outside a hospital setting, and includes both community-acquired pneumonia (CAP) and healthcare-associated pneumonia (HCAP) [11, 12]. According to the guidelines by the American Thoracic Society and the Infectious Diseases Society of America, HCAP is defined as pneumonia that occurs among patients who were hospitalized for 2 days or more in the prior 90 days, resided in a nursing home or extended care institution, received infusion therapy (including antimicrobial drugs), received long-term dialysis (including hemodialysis and peritoneal dialysis) within 30 days of entering the study, or had wound healing at home [11]. The Goto study enrolled all consenting adult patients with chest X-ray or computed tomography (CT) scan confirmation of pneumonia who sought medical care at either a hospital or clinic in Goto City [13, 14].

The study's main goals were to estimate all-cause, pneumococcal, and serotype-specific pneumococcal pneumonia incidence and antimicrobial susceptibility. The study did not have an intervention component and all participants received standard-of-care treatment.

**Study Sample for QALY Score/QALY Assessment**
The HRQoL analysis was conducted within a subset of the Goto Epidemiology Study. To be included in the HRQoL analysis, participants had to enroll in the Goto Epidemiology Study between 1 June 2017 (HRQoL study initiation) and 13 May 2018 and provide written informed consent. Participants' demographic characteristics and selected underlying comorbid conditions were documented. At-risk conditions included asthma, chronic obstructive pulmonary disease (COPD), congestive heart failure, chronic heart disease, autoimmune diseases (unless under systemic long-term steroid use or on biologics in which case the patient was considered high risk), and liver disease. High-risk conditions included the following: end-stage renal disease, organ transplant, immunodeficiency, immunosuppressive drug therapy, cancer (for solid tumors, current or recent history of active treatment), generalized malignancy, and splenectomy.

Participants were followed for 1 year after enrollment. Using simulation, we identified a required sample size of 360 patients; we increased this to 405 patients to account for either attrition or death.

**QALY Score Instruments**
Participants were administered the Japanese Versions of the EuroQol-5D-5L (EQ-5D-5L), the prespecified primary QALY score instrument for the study, the EQ-5D visual analog scale, and the Short Form-36 version 2 health survey (SF-36v2) [15, 16]. Responses from the latter instrument were used to derive the Short Form-6 Dimension health state classification instrument (SF-6D), an alternative QALY score [17]. Both the EQ-5D-5L and SF-6D are validated preference-weighted HRQoL instruments [8, 17–20]. This analysis reports the primary outcome for the study, EQ-5D-5L QALY scores and the QALYs derived from these scores.

The EQ-5D-5L is a 5-domain preference-weighted HRQoL instrument that addresses mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Each domain is rated on a 1 to 5 scale, where 1 equals best functioning (eg, “no problems”) and 5 equals worst functioning (eg, “extreme problems”). QALY scores were derived from these ratings by use of the published Japanese scoring rule [21].

**Periodic Administration of Instruments**
QALY scores were calculated for study days 0, 7, 15, 30, 90, 180, and 365 after diagnosis. During the day 0 interview participants were asked to assess both their current health and, via recall, their health 30 days before pneumonia diagnosis (referred to as day −30).

The EQ-5D-5L was administered via structured interview by Japanese interviewers who received training on the administration of HRQoL instruments in general as well as training on the 3 instruments used in the study. The study aimed at enrolling a broad range of patients regarding severity and wanted to minimize missing responses. To facilitate the inclusion of severe patients and their potential for missing responses during critical phases of the disease, if the participant was unavailable or unable to respond proxies were asked to respond instead. As per the study protocol, when a proxy was selected, priority was given to the primary caregiver, who was identified on enrollment in the study, followed by other proxies who were knowledgeable about the participant. The interviews were conducted either in person or by telephone.

**QALYs**
QALYs represent the area under the survival-weighted QALY score curve [22]. Points on the curve represent the product of the QALY scores and survival probabilities at each time point. The area under this curve was calculated by use of the trapezoidal method, which weights the height of the curve at the different measurement time points by the length of time that is represented by the time points [22]. Two sets of QALY estimates were made, one using unadjusted and a second using adjusted estimates of scores and survival probabilities.

**Analysis**
We calculated unadjusted means of the QALY scores at days 0, 7, 15, 30, 90, 180, and 365 and estimated adjusted means for these same intervals by use of a multivariable generalized linear model that accounted for multiple responses from the same participants. Ordinary least-squares regression was used...
to test if the day 0, 7, 15, 30, 90, 180, and 365 scores remained significantly below the initial day −30. Unadjusted survival probabilities were estimated by use of a Kaplan-Meier estimator. Adjusted survival probabilities were estimated by use of a multivariable parametric failure time model.

Participants with pneumonia served as their own controls by extrapolation of their recalled QALY scores for day −30 (assessed at day 0) to days 0, 7, 15, 30, 90, 180, and 365. First, we adjusted these scores to account for naturally occurring age- and gender-specific changes in scores calculated from Japanese EQ-5D-5L QALY score norms [23]. We estimated the unadjusted mean of these scores and used a GLM to estimate the adjusted mean. Average adjusted QALY score curves were created for patients both when they had pneumonia and when they served as their own control. Second, survival probabilities were derived by use of age- and gender-specific Japanese national mortality rates [24]. The mortality rates were adjusted upwards using an assumed relative risk of 2 to account for patients who developed pneumonia having a greater likelihood of comorbidity than the general population from whom the national mortality rates were derived [1]. Average adjusted survival curves were created for patients both when they had pneumonia and when they served as their own control. We evaluated the impact of this assumption by sensitivity analysis. Finally, survival-weighted QALY score curves were also created for patients both when they had pneumonia and when they served as their own control.

QALY’s lost were calculated as the difference between the areas under the survival-weighted QALY score curves for persons with pneumonia and for the same persons when used as their own controls. Standard errors, $P$ values, and 95% confidence intervals (CIs) for the QALY estimates were estimated by use of a nonparametric bootstrap.

We also assessed if 1-year QALY losses due to pneumonia differed between patients with COP who had outpatient evaluation only and those requiring hospitalization for their initial COP treatment.

In sensitivity analysis, we evaluated the effects of the adjustment for normally occurring changes (typically reductions) in scores with age (range, no change in scores to a doubling of the rate of change) and Japanese national mortality rates (range, equal to the national mortality rates to a quadrupling of the mortality rates).

The Institutional Review Board of Nagasaki University approved the study. Participants provided separate informed consents for the Goto Epidemiology and the HRQoL studies.

RESULTS

A total of 405 participants were enrolled. The mean age of study participants was 77.9 years (SD, 14.3); 84.9% were aged 65 years or older, 41.5% were female, 41.7% had HCAP, and 68.9% received hospital treatment for their initial pneumonia diagnosis (Table 1). Sixty-four percent of participants were at or high risk, including 21.5% with diabetes mellitus, 20.7% with COPD, 16.0% with congestive heart failure, and 15.3% with cancer.

The 405 study participants or their proxies provided responses for a total of 2959 time points for days −30, 0, 7, 15, 30, 90, 180, and 365. Participants provided 77.9% of these responses, followed by 11.0% from primary caregivers, and 11.1% from other proxies. Responses came mainly from face-to-face interviews (76.4%) and less frequently from telephone interviews (23.6%). All participants or their proxies completed all interviews if they were alive (ie, between patients and proxies, 100% compliance). A total of 291 (71.9%) participants or proxies completed the 1-year interview (ie, the remaining 28.1% of enrollees had died during the 1 year of follow-up after enrollment).

The average adjusted QALY score at day −30 was 0.759 (SE, .012; 95% CI, .735–.783). This declined to 0.561 (SE, .014; 95% CI, .534–.588) on diagnosis and increased to 0.689 (SE, .015; 95% CI, .660–.718) by day 365 (Table 2). None of the average scores at days 0, 7, 15, 30, 90, 180, and 365 returned to the level of the average day −30 score ($P < .001$ for all comparisons) (Table 2). Significant predictors of higher QALY scores included interviews further from the pneumonia diagnosis (eg, at days 90, 180, and 365 vs days 0, 7 and 15), higher day −30 EQ-5D-5L QALY scores, younger age, lower pneumonia severity index scores, and initial treatment in the outpatient setting (see Supplementary Tables 1 and 2, for coefficients and marginal effects of unit changes in the explanatory variables from the model predicting the scores, and Supplementary Tables 3 and 4, for coefficients and marginal effects for day −30 scores).

Figure 1 shows QALY curves among patients both when they had pneumonia and when they served as their own control.

| Table 1. Demographic and Clinical Characteristics of Patients With Pneumonia |
|---------------------------------------------------------------|
| Characteristics | Value (N = 405) |
| Age ≥65 years, % | 84.9 |
| Age, mean (SD), years | 77.9 (14.3) |
| Female, % | 41.5 |
| Healthcare-acquired pneumonia, % | 41.7 |
| Pneumonia severity index score, mean (SD) | 110.5 (38.2) |
| Initial pneumonia episode treated in hospital, % | 68.9 |
| At or high risk, % | 64.2 |
| Selected comorbid conditions, % | |
| Chronic obstructive pulmonary disease | 20.7 |
| Diabetes mellitus | 21.5 |
| Congestive heart failure | 16.0 |
| Cancer | 15.3 |
| End-stage renal disease | 10.9 |
| Asthma | 10.4 |
| Liver disease | 10.4 |
The average adjusted 365-day QALYs equaled 0.583 and 0.713 for participants with pneumonia and for participants when used as their own controls (compared to a maximum of 1 [365/365]). The difference was 0.13 QALYs (SE, .013; 95% CI, .105–.155; \( P < .001 \)) equivalent to 47.5 (0.13 × 365) quality-adjusted days. The average adjusted QALYs through day 30 after diagnosis equaled 0.561, 0.622, and 0.698 QALYs (equivalent to 3.7, 7.2, and 11.0 quality-adjusted days) through days 30, 90, and 180, respectively (Table 3). The difference (ie, QALYs lost) between pneumonia and control QALYs was 0.056; SE, 0.015; 95% CI, .028–.884; \( P < .001 \).

Within the ranges analyzed, our sensitivity analyses suggested that our assumptions about the relative risk (RR) for mortality and the natural decline in QALYs differ significantly between patients with COP who received outpatient services only and those requiring hospitalization for their initial COP treatment (0.091 and 0.147, respectively; \( P < .001 \)). QALY losses difference, 0.06; SE, 0.015; 95% CI, .028–.884; \( P < .001 \).

DISCUSSION

This is the first prospective study measuring QALY scores and losses among Japanese adult patients with clinically and radiographically confirmed pneumonia. The results of this study represent the strongest data available for the evaluation of pneumonia-prevention strategies in Japan. Future policy decisions for pneumococcal vaccination in adults may therefore use our study’s estimates to model the benefit of alternative vaccination strategies.

On average, adjusted QALY scores fell from 0.759 at day −30 before diagnosis to 0.561 at diagnosis and increased to 0.689 by day 365 after diagnosis. Estimated losses in adjusted QALYs were 0.011, 0.030, 0.060, and 0.130 QALYs (equivalent to 3.7, 11.0, 22.0, and 47.5 quality-adjusted days) through days 30, 90, 180, and 365, respectively. They represented between 16% (0.156/0.186) and 18% (0.0583/0.713) reductions of the QALYs projected for participants when they were used as their own controls. Differences in mortality also continued to increase throughout the 365 days. Thus, it is likely that greater losses would have been observed had there been longer follow-up.

For comparison purposes, a Japanese study reported QALY score losses of 0.06 for stroke and renal disease and of 0.13 for musculoskeletal disease among Japanese patients [25]. The 1-year QALY losses observed in our study of Japanese adult patients with CAP were similar to those for US adults for heart...
Figure 1. Construction of the QALY estimates for days 0 to 365. A, Average adjusted QALY score curves among patients both when they had pneumonia and when they served as their own control (i.e., reflecting the naturally occurring gender-specific downward trajectory of QALY scores with aging [“natural decline”] had they not had pneumonia). B, Average adjusted survival curves among patients both when they had pneumonia and when they served as their own control. C, Average adjusted survival-weighted QALY score curves and areas under these curves among patients both when they had pneumonia and when they served as their own control. The hatched area in panel C represents QALYs experienced by patients both when they developed pneumonia and when they served as their own controls. The cross-hatched area represents QALYS lost due to pneumonia. Abbreviation: QALY, quality-adjusted life-year.

Table 3. Unadjusted and Adjusted QALY Estimates and QALY Losses Among Patients With Pneumonia Through Day 365 After Diagnosis

| Study Day | Unadjusted results | Adjusted results |
|-----------|--------------------|------------------|
|           | Control QALYs      | Pneumonia QALYs  | QALY Differences |
|           | P                  | 95% Confidence Interval (Lower-Upper) |
|           |                    |                  |                  |
| 30        | 0.064              | 0.053            | 0.011             | 0.001             | <.001 | .009–.013 |
| 90        | 0.187              | 0.158            | 0.030             | 0.003             | <.001 | .024–.035 |
| 180       | 0.369              | 0.306            | 0.063             | 0.006             | <.001 | .051–.078 |
| 365       | 0.729              | 0.587            | 0.142             | 0.013             | <.110 | .105–.155 |

Abbreviations: EQ-5D-5L, EuroQol-5D-5L; QALY, quality-adjusted life-year.

aDifferences due to rounding.
bUncertainty estimates for QALYs calculated when participants served as their own controls. Patients include sampling uncertainty for the EQ-5D-5L scores and for the age and gender distribution in the sample (but not sampling uncertainty stemming from the mortality ratio). They do not include sampling uncertainty that stems from the measurement of the mortality rates themselves or in the measurements that went into the calculation of the natural decline in ED-5D-5L scores with aging.
failure, stroke, or chronic renal failure [26]. One-year QALY losses were significantly larger among patients with COP requiring hospitalization for their initial COP treatment than those who received outpatient care only.

QALYs are a function of the quality and length of survival. As expected, lower QALY scores after pneumonia diagnosis were associated with lower QALY scores at day –30, interviews closer to the pneumonia diagnosis, higher pneumonia severity index scores, older age, and hospital treatment for the initial diagnosis of pneumonia. Similarly, lower survival probabilities were associated with older age, pre-existing diagnoses of either cancer or immunosuppressive disease, and higher pneumonia severity index scores. Therefore, pre-existing underlying health status is an important determinant of QALYs after pneumonia.

Our analysis and the one by Mangen et al [27] are the first 2 long-term prospective longitudinal studies of postpneumonia QALY scores in the literature, and ours is the first in Japan. Other studies have reported cross-sectional or longitudinal

| Analysis                              | QALY Differences | QALY Differences, SE | P     | 95% Confidence Interval (Lower-Upper) |
|---------------------------------------|------------------|----------------------|-------|-------------------------------------|
| Unadjusted results                    |                  |                      |       |                                     |
| Baseline 30-day QALYs                 | 0.0101           | 0.0008               | <.001 | .0085–.0118                         |
| Mortality relative risk = 1           | 0.0102           | 0.0008               | <.001 | .0086–.0119                         |
| Mortality relative risk = 4           | 0.0100           | 0.0008               | <.001 | .0084–.0115                         |
| No natural decline                    | 0.0102           | 0.0008               | <.001 | .0086–.0118                         |
| Doubled natural decline               | 0.0101           | 0.0008               | <.001 | .0085–.0117                         |
| Baseline 90-day QALYs                 | 0.0296           | 0.0027               | <.001 | .0244–.0349                         |
| Mortality relative risk = 1           | 0.0305           | 0.0027               | <.001 | .0252–.0357                         |
| Mortality relative risk = 4           | 0.0279           | 0.0027               | <.001 | .0226–.0332                         |
| No natural decline                    | 0.0298           | 0.0026               | <.001 | .0247–.0349                         |
| Doubled natural decline               | 0.0294           | 0.0027               | <.001 | .0241–.0347                         |
| Baseline 180-day QALYs                | 0.0631           | 0.0050               | <.001 | .0633–.0728                         |
| Mortality relative risk = 1           | 0.0665           | 0.0051               | <.001 | .0565–.0764                         |
| Mortality relative risk = 4           | 0.0564           | 0.0052               | <.001 | .0482–.0665                         |
| No natural decline                    | 0.0837           | 0.0050               | <.001 | .0540–.0734                         |
| Doubled natural decline               | 0.0624           | 0.0051               | <.001 | .0524–.0724                         |
| Baseline 365-day QALYs                | 0.1424           | 0.0095               | <.001 | .1273–.1611                         |
| Mortality relative risk = 1           | 0.1561           | 0.0099               | <.001 | .1366–.1756                         |
| Mortality relative risk = 4           | 0.1561           | 0.0102               | <.001 | .0961–.1361                         |
| No natural decline                    | 0.1447           | 0.0099               | <.001 | .1254–.1640                         |
| Doubled natural decline               | 0.1401           | 0.0098               | <.001 | .1210–.1592                         |
| Adjusted results                      |                  |                      |       |                                     |
| Baseline 30-day QALYs                 | 0.0108           | 0.0009               | <.001 | .0091–.0125                         |
| Mortality relative risk = 1           | 0.0110           | 0.0009               | <.001 | .0093–.0127                         |
| Mortality relative risk = 4           | 0.0105           | 0.0009               | <.001 | .0088–.0125                         |
| No natural decline                    | 0.0109           | 0.0008               | <.001 | .0092–.0126                         |
| Doubled natural decline               | 0.0108           | 0.0009               | <.001 | .0091–.0125                         |
| Baseline 90-day QALYs                 | 0.0303           | 0.0027               | <.001 | .0250–.0356                         |
| Mortality relative risk = 1           | 0.0317           | 0.0027               | <.001 | .0264–.0371                         |
| Mortality relative risk = 4           | 0.0275           | 0.0027               | <.001 | .0223–.0328                         |
| No natural decline                    | 0.0305           | 0.0026               | <.001 | .0253–.0356                         |
| Doubled natural decline               | 0.0301           | 0.0027               | <.001 | .0249–.0355                         |
| Baseline 180-day QALYs                | 0.0605           | 0.0056               | <.001 | .0494–.0715                         |
| Mortality relative risk = 1           | 0.0660           | 0.0057               | <.001 | .0547–.0772                         |
| Mortality relative risk = 4           | 0.0502           | 0.0057               | <.001 | .0389–.0614                         |
| No natural decline                    | 0.0610           | 0.0055               | <.001 | .0501–.0718                         |
| Doubled natural decline               | 0.0599           | 0.0058               | <.001 | .0485–.0713                         |
| Baseline 365-day QALYs                | 0.1302           | 0.0124               | <.001 | .1060–.1545                         |
| Mortality relative risk = 1           | 0.1612           | 0.0126               | <.001 | .1266–.1758                         |
| Mortality relative risk = 4           | 0.0935           | 0.0128               | <.001 | .0684–.1186                         |
| No natural decline                    | 0.1319           | 0.0122               | <.001 | .1081–.1558                         |
| Doubled natural decline               | 0.1286           | 0.0128               | <.001 | .1034–.1536                         |

Abbreviation: QALY, quality-adjusted life-year.
assessments of quality of life but did not assess QALYs [24, 28–33]. One study used the preference-weighted EQ-5D 3-level instrument to assess QALY scores 1 year after diagnosis, but given there was no baseline assessment this study was unable to assess QALYs or QALY losses [34]. Another study used the time-tradeoff method among parents and healthy members of the community to assess QALY losses for moderate and severe pneumonia among children [35].

There were a number of difference between Mangen et al’s [27] and our study: country, source of patients, treatment setting, period of follow-up, and preference score administration. Additionally, Mangen et al used for controls a separate population without pneumonia versus the self-control design we used. Nevertheless, both studies reported a 1-year QALY loss of 0.13, although Mangen et al’s 0.13 arose from QALY estimates of 0.81 for subjects without disease versus a 0.68 QALY for patients with suspected pneumonia, whereas ours arose from QALY estimates of 0.71 and 0.58, respectively.

Estimates of QALY scores and QALY losses are central to the evaluation of the cost-effectiveness of pneumococcal vaccination. None of the cost-effectiveness studies used pneumonia-specific scores, but rather have generally used scores based on perceived health status associated with limited activities of daily living [36]. In general, the QALY losses assumed by these and 2 key US studies [37, 38] are much smaller than the estimates calculated in the study by Mangen et al and in our study.

Given that our study was performed in Japan and used Japanese HRQoL instruments, our results may apply primarily to Japan. Outside of Japan, additional studies may well be conducted in other populations and countries. Nevertheless, until that time, Mangen et al’s [27] and our results are the best available data for informing current models, such as burden of illness studies and cost-effectiveness analyses in Japan and elsewhere, that require estimates of QALY losses after onset of pneumonia.

Our study had several limitations. First, as study enrollment was triggered by the diagnosis of pneumonia, we were unable to assess HRQoL before pneumonia onset. We instead used a recalled assessment at 30 days before hospitalization, which is supported by several studies that have found reasonable accuracy of recalled EQ-5D and SF-36 scores [39–42]. Second, we used adjusted Japanese lifetables for calculation of survival probabilities. These lifetables are reported by gender and age, but not by comorbidity, for the average population. However, within age and gender subgroups, those who develop pneumonia may have a different comorbidity burden than those who do not. Thus, the average survival probabilities for the general population may not be applicable to participants who developed pneumonia. We attempted to address this issue by assuming a 2-fold increased mortality risk in our population and varying this risk in sensitivity analysis between 1 (background mortality rate) and 4 times.

In conclusion, our study is 1 of only 2 studies that report longitudinal prospective data on QALY scores and associated QALYs lost due to pneumonia. We found a substantial 1-year loss following pneumonia diagnosis equivalent to 47.5 quality-adjusted days. By day 365, QALY scores had not yet returned to baseline levels and survival differences were increasing over time, suggesting that QALY scores may remain diminished and QALY losses may continue to increase beyond 1 year. We acknowledge that different settings may have varying QALY decrements, and thus that additional studies would be useful. Until this occurs, our results, combined with those of Mangen et al [27], provide the most robust results for assessing QALY decrements as part of a full public health evaluation of adult pneumonia-prevention strategies, such as pneumococcal and influenza vaccination programs.

Supplementary Data
Supplementary materials are available at Clinical Infectious Diseases online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes
Author contributions. H. A. G. and J. A. S. drafted the manuscript, had full access to all the data in the study, and take responsibility for the integrity of the data and the accuracy of the data analysis. All authors developed the study concept and design, critically reviewed drafts of the manuscript and approved the final version, and were involved in the acquisition, analysis, and/or interpretation of the data.

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