Incidence and Duration of Hospitalizations Among Persons with AIDS: An Event History Approach

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Objective. To analyze hospitalization patterns of persons with AIDS (PWAs) in a multi-state/multi-episode continuous time duration framework.

Data Sources. PWAs on Medicaid identified through a match between the state's AIDS Registry and Medicaid eligibility files; hospital admission and discharge dates identified through Medicaid claims.

Study Design. Using a Weibull event history framework, we model the hazard of transition between hospitalized and community spells, incorporating the competing risk of death in each of these states. Simulations are used to translate these parameters into readily interpretable estimates of length of stay, the probability that a hospitalization will end in death, and the probability that a nonhospitalized person will be hospitalized within 90 days.

Principal Findings. In multivariate analyses, participation in a Medicaid waiver program offering case management and home care was associated with hospital stays 1.3 days shorter than for nonparticipants. African American race and Hispanic ethnicity were associated with hospital stays 1.2 days and 1.0 day longer than for non-Hispanic whites; African Americans also experienced more frequent hospital admissions. Residents of the high-HIV–prevalence area of the state had more frequent admissions and stays two days longer than those residing elsewhere in the state. Older PWAs experienced less frequent hospital admissions but longer stays, with hospitalizations of 55-year-olds lasting 8.25 days longer than those of 25-year-olds.

Conclusions. Much socioeconomic and geographic variability exists both in the incidence and in the duration of hospitalization among persons with AIDS in New Jersey. Event history analysis provides a useful statistical framework for analysis of these variations, deals appropriately with data in which duration of observation varies from individual to individual, and permits the competing risk of death to be incorporated into the model. Transition models of this type have broad applicability in modeling the risk and duration of hospitalization in chronic illnesses.

Key Words. Hospitalization, AIDS, HIV, event history, methods

Although AIDS care increasingly emphasizes community-based service delivery and pharmaceutical treatment, hospitalization is still its most costly component. These costs have substantially affected the healthcare system (Andrulis et al. 1992; Green and Arno 1990; Rosenblum, Buehler, Morgan, et al. 1993; Hellinger 1993; Solomon, Stein, Flynn, et al. 1998). To the extent that PWAs can receive the care they need without requiring hospitalization, both cost containment and quality of life goals can be advanced. It is therefore important that determinants of inpatient hospital use be better understood and that methods for modeling such use be improved. As in other chronic illnesses involving repeated hospital admissions, analyzing patterns of hospital use over time in HIV disease is a complex problem for which event history methods are useful. In this article, we illustrate the use of a multi-state/multi-episode continuous time duration model to model both the incidence and duration of hospitalizations among Medicaid beneficiaries with AIDS in New Jersey. Such models, which frame hospital use as a series of transitions among states, have considerable utility for improving analyses of the use of hospitals and other healthcare services over time.

Published studies offer an often confusing and inconsistent picture of AIDS-related hospitalization patterns. Variations in results reflect differences in measures of hospital use (e.g., number of admissions, length of stay, cumulative days, or cost of care), site of study, the stage of illness represented (e.g., inclusion or noninclusion of the terminal period of illness), and other methodological differences. While women, injection drug users, and minorities are becoming more prevalent in the HIV/AIDS population (Centers for Disease Control and Prevention [CDC] 1997), prior results are inconsistent with regard to the impact of these characteristics on hospital

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This research was funded by grants from the Agency for Health Care Policy and Research (R01-HS06339) and from the National Institute of Drug Abuse (R01-DA11362). The findings and opinions reported here are those of the authors and do not necessarily represent the views of any other individuals or organizations.

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use. This demographic shift also contributes to the increasing importance of Medicaid as a payer for HIV/AIDS care, because these subgroups are especially likely to rely on Medicaid as the payer for their care (Hellinger 1992).

In the present study, we use Medicaid claims histories from 1,401 AIDS patients in New Jersey to study differences in the use of inpatient services by race/ethnicity, gender, AIDS risk group, region, severity of illness, and year of service. Because the number of inpatient days used depends on variations in the hazard of admission and, once admitted, of discharge to the community or death, we model these hazards simultaneously with a continuous time duration model that includes death as an absorbing state. It is important to distinguish these aspects of the hospitalization process, because factors that affect the rate of admissions may differ from those that affect length of stay. For example, variations in rates of admission may depend on factors associated with access to outpatient medical and pharmaceutical care that could prevent episodes of severe opportunistic infections (Hurley, Freund, and Paul 1993; Turner et al. 1994; Horner, Bennett, Achenbach, et al. 1996). Factors most likely to affect length of stay may include housing difficulties, availability of informal or formal home care, and other social factors affecting hospital discharge (Williams, Zyzanski, and Wright 1992), variations in severity of illness (Kelly, Ball, and Turner 1989), and comorbidities related to such factors as illicit drug use (Cherubin and Sapira 1993).

Much of the previous work has relied on survey-based studies such as the AIDS Cost and Service Utilization Study (ACSUS). Hellinger (1993), for example, used ACSUS data to estimate that increased use of outpatient services began by about 1992 to supplant, rather than simply augment, inpatient hospital care, reversing what until that point had been a steady trend toward higher per case cost. However, information from ACSUS and other survey-based studies is limited by the fact that such studies do not capture the terminal period of HIV illness during which much hospitalization takes place. ACSUS, for example, interviewed respondents at six-month intervals about healthcare services used during the previous six-month period; services used after the respondent's last interview were not captured. Furthermore, individuals who are acutely ill or hospitalized may be unable to be interviewed in survey-based studies.

Gender effects have varied from study to study. Because gender differences in HIV have been noted in susceptibility to various opportunistic infections (Minkoff and DeHovitz 1991), access to outpatient care (Weissman,

Melchior, Huba, et al. 1995), and additional psychosocial factors (Weissman and Brown 1995), it is important to examine whether these factors create gender differences in hospital admission or discharge. Racial variations are also a topic of concern. Most length of stay studies have found significantly longer stays for African American and Hispanic PWAs (Kelly, Ball and Turner 1989; Hellinger 1993; Piette, Mor, Mayer, et al. 1993). This might reflect differences in severity of illness or might involve differences in informal caregiving, stability of housing, or other social factors. Other factors that could affect hospitalization patterns by race may include greater emergency room use because of the lack of a primary care physician (Mor et al. 1992), lower antiviral utilization (Moore et al. 1991), or less widespread use of antibiotic prophylaxis to prevent pneumocystis carinii pneumonia (Piette, Stein, Mor, et al. 1991), all of which may vary by race even among individuals with the same payer, such as Medicaid.

Injection drug use history may be an important indicator of differential health needs and problems related to drug dependence. Seage et al. (1993) have suggested that drug users are at risk for longer hospitalizations because of the lack of home supports on which they can rely for informal care. Similarly, Bennett et al. (1992) reported long lengths of stay among drug users, which they attributed to problems with discharge because of unstable housing. Ettner and Weissman (1994), however, found that drug users have as much access to informal care as male homosexuals with AIDS. Studies have varied in the way in which injection drug users are identified: for example, studies using administrative data often rely on episodes of healthcare attributed to drug abuse to identify this population. In such studies, those identified as drug users may be a nonrandomly selected subsample of drug users more likely to use medical services (Markson, McKee, Mauskopf, et al. 1994).

Most prior studies suggest length of stay among AIDS patients has declined over time (Markson, McKee, Mauskopf, et al. 1994; Andrulis, McGregor, Weiss, et al. 1995). Regional differences in length of stay have often been observed. Generally, the Northeast, particularly the New York area, has historically been an area of relatively high inpatient utilization among PWAs, and more than 7 percent of all inpatient days in public hospitals have been attributed to HIV care (Kelly, Ball, and Turner 1989; Andrulis, McGregor, Weiss, et al. 1995; Cohn, Klein, Weinstein, et al. 1996). At a more detailed level of geographic analysis, previous work suggests that care patterns in areas of high HIV prevalence, which also tend to be areas with high poverty rates and overburdened healthcare providers, may differ from care patterns in areas of moderate and lower HIV prevalence. In New Jersey, the high-prevalence

area is the area closest to New York City, embracing such cities as Newark, Jersey City, and Paterson.

Use of hospital services also varies across care systems. Some of the New Jersey Medicaid population is enrolled in an HIV-specific Medicaid home and community-based care waiver program, the AIDS Community Care Alternatives Program (ACCAP), which offers case management and private duty nursing among other services (Merzel, Crystal, Sambamoorthi, et al. 1992). Access to such home and community based services may be associated with less inpatient utilization (Cohn, Klein, Weinstein, et al. 1996; Cunningham, Mosen, Hays, et al. 1996; Sowell, Gueldner, Killeen, et al. 1992). Age is also a potentially important factor in patterns of hospital use. Only a few studies have examined the effect of advanced age on the utilization of inpatient services among PWAs, with mixed results. Kelly, Ball, and Turner (1989) found that PWAs age 45 to 64 had a statistically significant 4.25 days longer average length of stay relative to PWAs less than 25 years old. Turner et al. (1994), who found that older AIDS patients have a lower risk of hospital admission, attributed the finding to greater financial and social resources that allow them to avoid hospitalization.

Modeling methods in prior work have varied considerably. Some studies have focused primarily on length-of-stay variations and others on frequency of admissions. Lancaster and Intrator (1998) used a transition model to analyze frequency of hospitalization jointly with survival time but did not model length of stay; they used ACSUS data, which do not include the crucial period at the end of life. To understand the process that determines inpatient utilization, however, it is important to analyze simultaneously both the frequency of hospitalization (in economic terminology, the extensive margin of care) and the duration of each hospitalization (the intensive margin of care), both of which are intimately related to cost. The modeling approach we illustrate here makes it possible to do so.

DATA

We use New Jersey Medicaid claims data for persons diagnosed with AIDS between January 1988 and June 1992. AIDS diagnosis was based on information in New Jersey's AIDS Registry, using the 1987 Centers for Disease Control case definition (CDC 1987). The study population was identified through a match between Medicaid eligibility files and the state's AIDS Registry; Medicaid claims histories for identified cases were then extracted

from Medicaid claims files. The registry-match approach is believed to provide better sensitivity and specificity than the main alternative, screening healthcare claims for diagnostic codes suggestive of HIV disease. This latter method creates the possibility of bias related to "confounding by indication," because treatment for AIDS-related conditions increases the likelihood that an individual will be identified as a member of the study population (Kelly, Ball, and Turner 1989; Ball and Turner 1991). Claims data, because they do not depend on a respondent's availability for interview, include all services used up until death. Thus, use of claims histories, in contrast to retrospective interview-based reports that frequently exclude the last months of life, makes it possible to observe healthcare use over the full course of illness, including the terminal period of illness during which a large proportion of healthcare expenditures take place (Fleishman, Mor, and Laliberte 1995). This may also be the period during which the greatest opportunities exist to minimize hospitalization through providing home and community-based services.

Inclusion criteria included: Medicaid participation between August 1989 and July 1991; diagnosis with AIDS by June 30, 1992; age 18 or over at the time of diagnosis; receipt of Medicaid services for at least some part of the period from AIDS diagnosis to death or the last date of observation; a single continuous spell of Medicaid participation for some or all of the period from diagnosis to death/censoring as opposed to an intermittent pattern with multiple interrupted spells of Medicaid participation; and the absence of inconsistencies that were occasionally identified in an individual's claims, such as Registry-reported death 30 days or more before the last date of service. A total of 2,464 persons meeting these criteria were identified, including 1,401 whose use of service was observed for the complete period from AIDS diagnosis until death or June 1994, the last date for which data were available, and 1,063 whose observation began after AIDS diagnosis (left-censored). The former group of 1,401, 95 percent of whom were followed until death, is our analytic sample. Comparisons with the full population (including left-censored cases) were performed as a check for sensitivity of subgroup comparisons to inclusion criteria. In general, patterns were quite similar for the completely observed and full study populations. For example, we compared number of admissions per person and length of hospital stays by race/ethnicity, gender, risk group, region, waiver status, and age, for the full and completely observed groups. For each independent variable, differences were in the same direction for both groups, both for admissions and length of stay. An appendix containing descriptive statistics and multivariate results for the full sample is available from the authors by request.

The 1,401 cases experienced 4,233 inpatient hospital stays and 4,643 spells in the community, for a total of 8,876 spells in and out of the hospital. Among the 95 percent whose death was observed, 721, or 54 percent, died in the hospital. The mean number of spells in the hospital and in the community was about seven, with a median of five. Mean duration of hospitalized spells was 17 days, while mean duration of community spells was 129 days. Other descriptive statistics are provided in Table 1.

Among the study population, 37 percent were women, 71 percent were injection drug users, 58 percent were African American, and 17 percent were Hispanic. Seventy-one percent lived in the high-HIV–prevalence region of the state. Thirty-two percent were enrolled in the waiver program (ACCAP) at some point during the observation period. Mean age at AIDS diagnosis was 36. Most of the inpatient stays (85 percent) occurred between 1989 and 1992.

Inpatient claims included ICD-9 diagnosis codes indicating the primary diagnosis associated with the hospital stay. Using the AIDS severity classification system for AIDS hospitalizations (SCAH) of Turner, Kelly, and Ball (1989), we computed a severity index for each inpatient hospitalization. Scale scores range from 1.0 to 3.4, representing increasingly severe AIDS-related illness. The system was developed to help provide staging information in situations in which highly detailed clinical information (such as CD4+ cell count) on AIDS patients is not available to the researcher. The index provides additional information regarding the health status of PWAs admitted to the hospital and serves as an additional predictor variable to help explain length of hospital stays. As expected, hospitalizations with high severity were more likely to end in death: this was the case for 28 percent of hospitalizations with a severity index of 3.4 versus 16 percent of hospitalizations with a severity index of 1.0. The average severity level in our sample was 1.5.

METHODS

To parsimoniously consider both the number of stays and the length of stay within a single model, we use a multi-state/multi-episode framework (Flinn and Heckman 1982) that can incorporate multiple distinct states into which repeated transitions occur over time. This event history approach explicitly distinguishes the factors predicting incidence of hospitalization from those predicting its duration and controls for the rate of transition from the hospital or community to death. In our case there are three distinct states: in the

Table 1: Descriptive Statistics and Variable Definitions (n = 1,401, Unless Otherwise Noted)

Variable: Description	*Mean (s.d.)*
Average number of hospital spells per person	3.021
	(3.034)
Average number of community spells per person	3.314
	(3.052)
Average length of nonterminal hospital spells (n = 3512)	15.440
	(17.505)
Average length of terminal hospital spells (n = 721)	23.184
	(27.372)
Average per person length of hospital spells	18.667
	(21.716)
Average length of nonterminal community spells (n = 4038,	129.530
percentage censored = 1.9%)	(207.464)
Average length of terminal community spells (n = 605)	126.896
	(218.039)
Female	0.365
Injection drug users	0.707
African American	0.577
Hispanic	0.168
Near NYC (Bergen, Essex, Hudson, Passaic, or Union County)	0.713
Waiver: Indicates enrollment in the New Jersey home care waiver program	0.323
Age	35.938
	(7.905)
Severity index (n = 4233)	1.505
	(0.687)
Survival (months)	
< 3	0.263
3–6	0.121
6–12	0.161
12–18	0.111
18–24	0.090
> 24	0.254
Year of Service (n = *4233)*	
1988	0.031
1989	0.161
1990	0.260
1991	0.267
1992	0.165
1993	0.087
1994	0.028

hospital, in the community, or deceased. A PWA may enter and exit the hospital multiple times after AIDS diagnosis, but death is an absorbing state. This model provides a unified framework in which we can estimate the effects of variables of interest on time in the hospital, time in the community, and transitions from the hospital or community to death.

The multi-state/multi-episode model has been used in several economic applications (Flinn and Heckman 1982; Burdett, Keifer, and Sharma 1985), and transition models, such as Markov models, have long been used by sociologists to describe event histories (Coleman 1964; Tuma, Hannan, and Groeneveld 1979). Markov models impose an underlying exponential distribution on the survivor function, implying that the rate of exit occurs independently from the length of the spell; this assumption is often difficult to justify in practice and this is certainly the case in analyzing hospitalization. Our model is semi-Markovian because it assumes a Weibull hazard framework to estimate the underlying transition rates, allowing for positive or negative duration dependence in the length of the spells in or out of the hospital. Positive duration dependence implies that the rate of exit from the state increases as time passes, while negative duration dependence implies the opposite. Liu, Coughlin, and McBride (1991) used a Weibull hazard framework to examine transitions between residence in a nursing home and the community as well as transitions into death. However, they did not estimate all of the transition rates simultaneously, as we do in this article; doing so is preferable from the point of view of statistical efficiency.

At every instant a PWA occupies one of three states: in the hospital (state H), in the community (state C), or dead (state D). We specify four hazards, one for each feasible transition from one state into another, which under the assumption of a Weibull distribution is:

$$h_{ij}(t; x_{ij}, \gamma_{ij}) = \alpha_{ij} t^{(\alpha_{ij}-1)} \exp(x_{ij}' \gamma_{ij})^{\alpha_{ij}}, \tag{1}$$

where $h_{ij}(.)$ represents the transition rate from state i to state j (we have suppressed the person-level subscripts for notational convenience), x_{ij} represents observables, γ_{ij} represents the unknown parameters to be estimated, and the α_{ij} are the shape parameters for the Weibull distribution. When an α_{ij} is greater than unity, the state exhibits positive duration dependence; when an α_{ij} is less than unity, the state exhibits negative duration dependence.

The starting point for each PWA is the date of clinical AIDS diagnosis as it was recorded in the New Jersey AIDS Registry, based on the incidence of specific opportunistic infections in accordance with the Centers for Disease Control 1987 case definition (CDC 1987). The transition model assumes that

conditional on covariates in the model, transitions from state to state depend only on the most recent state and not on earlier states. Time in our model is specified as the number of days since AIDS diagnosis. Each time a person enters or exits the hospital, a new spell is started. Under the semi-Markov assumption of spell independence, the contribution to the likelihood function from the pth spell and the subsequent transition out of the currently occupied ith state is represented by the following expression:

$$g_{ij}(t_p|x_{ij}, \gamma_{ij}) = h_{ij}(t_p; x_{ij}, \gamma_{ij})\,[1 - G(t_p|X; \Gamma)], \tag{2}$$

where X represents the set of all independent variables and Γ represents the set of all parameters to be estimated, and where

$$1 - G(t_p|X, \Gamma) = \exp[-\int_{\phi}^{t_p} h_i(t; X, \Gamma)dt], \tag{3}$$

which is the survivor function, and

$$h_i(t; X, \Gamma) = \Sigma_{j=H,C,D;j\neq i} h_{ij}(t; x_{ij}, \gamma_{ij}), \tag{4}$$

which is the hazard of transition out of state i. The form of the multi-state/multi-episode hazard framework implies that if, for instance, a PWA is currently in the hospital, death and returning to the community represent competing risks for the person on each day of the hospitalization. The likelihood function for a particular person multiplicatively combines the relevant version of Equation 2 for each spell, except for final spells of still living PWAs, which are censored. Maximum likelihood estimation is used to estimate the joint likelihood function.

RESULTS

Descriptive and Ordinary Least Squares Results

Table 2 shows bivariate differences in the number of hospital admissions (with the person as the unit of analysis) and hospital length of stay (with the hospitalization as the unit of analysis) for the fully observed sample. In this bivariate table, the observed number of admissions is shown, without controlling for differences in length of observation. Hospital stays were significantly longer for African Americans than for whites (17.4 versus 15.1 days). Injection drug users had more admissions but no significant difference in length of stay. Persons residing in the counties near New York City had stays that averaged three days longer than those of PWAs residing elsewhere in the state, but

Table 2: Number of Admissions per Person and Length of Hospital Stays Among Completely Observed Sample

	Admissions		*Length of Stay*	
Category	*Mean*	n	*Mean*	n
Race/Ethnicity				
African American	3.13	809	17.38***	2,535
Hispanic	3.02	235	16.88	709
White/Other	2.77	357	15.08	989
Gender				
Male	2.97	890	16.95	2,644
Female	3.11	511	16.44	1,589
Risk Group				
IDU	3.08**	990	16.68	3,047
Non-IDU	2.89	411	16.97	1,186
Region				
Near NYC	3.01	999	17.62***	3,009
Rest of state	3.04	402	14.64	1,224
Waiver Status				
ACCAP	3.52***	452	15.32***	1,591
Non-ACCAP	2.78	949	17.63	2,642
Age				
18–29	3.65***	273	14.35***	996
30–39	3.01	746	16.41	2,249
40–49	2.77	302	18.95	836
≥ 50	1.90	80	25.67	152
Follow-up (months)				
< 3	0.95***	369	22.11***	349
3–6	1.82	169	24.10	307
6–12	2.38	226	20.32	539
12–18	3.56	155	18.35	552
18–24	4.34	126	15.69	547
> 24	5.45	365	13.50	1,939
Severity				
1.0–1.9	–	–	15.74***	3,318
2.0–2.9	–	–	20.17	512
3.0–3.4	–	–	20.84	403
Year of Service				
1988	–	–	25.92***	133
1989	–	–	21.86	683
1990	–	–	17.20	1,101
1991	–	–	14.89	1,131

continued

Table 2: Continued

	Admissions		Length of Stay	
Category	Mean	n	Mean	n
1992	–	–	14.74	700
1993	–	–	13.63	368
1994	–	–	12.35	117

*Joint statistically significant difference at the 10% level.

**Joint statistically significant difference at the 5% level.

***Joint statistically significant difference at the 1% level.

had similar numbers of admissions. Waiver participants had more admissions (apparently related to their longer survival), but their admissions averaged 2.3 fewer days in length. Respondents over age 50 had fewer but longer hospital stays, averaging 26 days in length.

In the bivariate comparisons, hospital length of stay declined over time, with mean length of stay falling from 26 days in 1988 to 12 days in 1994; most of the change occurred in the 1988–1990 period. Most individuals who were hospitalized in 1993 and 1994 survived the study period, so that only a few of the 1993 and 1994 hospitalizations took place in the terminal period of HIV illness. This may have downwardly biased length of stay estimates for those years, but it appears clear that there was a trend toward shorter stays over the 1988–1994 period, particularly between 1988 and 1990. Higher levels of the severity index tended to correspond to longer lengths of stay, with severity ratings below 2 associated with an average length of stay of more than four days less than those with ratings between 2 and 3. However, little additional increase in length of stay was associated with the highest severity ratings, 3 and above, perhaps because such hospitalizations were twice as likely to end in death as hospitalizations with a severity rating below 3.

To provide an initial multivariate assessment of hospitalization patterns, Table 3 presents ordinary least squares (OLS) estimates of the number of inpatient admissions and length of hospital stay. The first column displays results from an OLS regression in which each person's number of inpatient admissions is the dependent variable. Year of service dummies are excluded in this column because the dependent variable represents an aggregate of the number of hospital admissions over the period from AIDS diagnosis to death or censoring, which can involve several calendar years. For hospital admissions, the severity index variable is averaged over all hospital stays and is set to 1, the lowest level, for persons without any inpatient admissions in the

observation period (0 is not defined on the severity scale). Because different patients have different lengths of observation over which they are at risk of hospitalization, the regressions in Table 3 include the number of survival months as a covariate. Thus, like the event history model results presented later on in Tables 4 and 5, these results control for variations in duration of exposure.

The hospital admission results in Table 3 are similar in many respects to the bivariate results, but with some noteworthy differences. In contrast to the bivariate results (Table 2), the regression analysis with adjustment for duration of exposure indicates that African American race or Hispanic ethnicity is associated with more frequent admissions. The effect of waiver program participation on admissions is smaller in the regression model: 0.25 as opposed to the bivariate difference of 0.74. The large 1.75 bivariate difference in mean inpatient admissions between PWAs aged 18 to 29 and PWAs aged 50 and over was halved in the regression framework. However, the pattern of fewer hospitalizations for older PWAs remains prominent in the multivariate model.

The decline over time in length of stay was less substantial in the regression than in the bivariate comparisons, suggesting that some of the trend to shorter stays results from changing case mix (e.g., changes in severity). As in the bivariate results, PWAs in the high-prevalence region of the state had longer stays. There was a trend ($p < .1$) toward longer hospital stays by African Americans and (in contrast to the bivariate results) toward longer hospital stays by women. Waiver participants tended to have shorter lengths of stay than nonparticipants, but the result was only marginally significant and was about half the size of the bivariate difference in mean length of stay by waiver participation. As in the bivariate results, more severely ill patients had significantly longer lengths of stay.

Despite providing the ability to statistically control for multiple covariates that affect the frequency and duration of admissions, the regression models reported in Table 3 provide an insufficient representation of the process of inpatient utilization and are subject to several statistical problems. Separately estimating models for length of stay and frequency of admissions is statistically inefficient, and it is less than desirable to conduct part of the analysis (length of stay) at the hospitalization level and part (frequency of admissions) at the individual level. The competing risk of death cannot be appropriately incorporated into this framework. A more fundamental difficulty with the OLS regression approach involves the way in which duration is statistically represented. The number of admissions experienced by an individual reflects the combined influence of frequency of admissions and duration of time

Table 3: Ordinary Least Squares Estimates of Inpatient Utilization Within Completely Observed Sample (Standard Errors in Parentheses)

Independent Variables	*Admissions*	*Length of Stay*
Female	0.115	−1.070*
	(0.140)	(0.627)
IDU	0.205	−0.867
	(0.149)	(0.691)
African American	0.653***	1.505*
	(0.169)	(0.777)
Hispanic	0.477**	1.482
	(0.210)	(0.961)
Near NYC	0.062	1.636**
	(0.157)	(0.697)
Waiver	0.246*	−1.246*
	(0.149)	(0.636)
Severity	0.558***	2.209***
	(0.088)	(0.432)
Age (18–29 omitted)		
30–39	−0.298*	1.994***
	(0.177)	(0.756)
40–49	−0.444**	4.288***
	(0.208)	(0.923)
≥ 50	−0.811***	9.425***
	(0.313)	(1.683)
Survival Months (< 3 omitted)		
3–6	0.779***	3.140**
	(0.228)	(1.503)
6–12	1.351***	−0.791
	(0.208)	(1.328)
12–18	2.535***	−1.787
	(0.236)	(1.334)
18–24	3.244***	−4.181***
	(0.257)	(1.344)
> 24	4.397***	−5.695***
	(0.186)	(1.191)
Year of Service (1989 omitted)		
1988	–	5.189**
		(2.268)
1990	–	−3.924
		(3.264)
1991	–	−5.412
		(4.503)

continued

Table 3: Continued

Independent Variables	*Admissions*	*Length of Stay*
1992	–	−4.633
		(5.835)
1993	–	−4.234
		(7.223)
1994	–	−5.702
		(8.708)
Constant	−0.223	22.228***
	(0.281)	(2.292)
R^2	0.365	0.069
Sample size	1401	4233

*Statistical significance at the 10% level.

**Statistical significance at the 5% level.

***Statistical significance at the 1% level.

during which the individual is observed and at risk of hospitalization. In Table 3, survival is used as an independent variable, but death actually represents an outcome that can be seen as constituting a competing risk to the risk of hospitalization or (once hospitalized) of discharge. Adding indicator variables to the model representing survival categories (3–6 months, 6–12 months, etc.) reduces bias associated with differential survival but is a rather inefficient way of doing so. A more appropriate statistical representation is one that corresponds more closely to the longitudinal nature of the hospitalization process as a series of transitions taking place over time. In a continuous-time event history, duration is handled in a more natural fashion, mortality can be treated appropriately as a competing risk, and severity can be handled as a time-varying covariate rather than in the artificial, time-invariant fashion reflected in Table 3.

In the following section, we report results of an event history analysis in which the hazards of hospital-to-community, hospital-to-death, community-to-hospital, and community-to-death transitions are simultaneously modeled. Because the instantaneous probability of a transition to or from the hospital is modeled, this approach by its nature deals appropriately with varying lengths of observation.

Duration Model Results

Table 4 displays the results for the four hazard functions estimated within the event history framework. Severity and year of service vary throughout

the event history of a person, as time passes and hospital admissions take place. These variables are omitted from the hazards representing transitions out of the community because there is no associated severity measure for a community spell, and spells in the community may span a year or more, making year of service difficult to interpret. The parameter estimates are interpreted as effects on the rate of transition from the current state to another state; thus, negative parameter estimates tend to indicate longer spell lengths in the given state associated with the independent variable. Later we use the parameter estimates from the event history model to estimate predicted values for length of stay, the terminal hospitalization probability, and the probability of hospital admission within 90 days.

Results of the transition model indicate that hospitalized participants in the home and community-based care waiver program exhibited a higher rate of transition to the community, consistent with the OLS findings of shorter length of stay. However, waiver participants in the community experienced no difference in the hazard of hospital admission from the community. It appears possible that the ready availability of home care services, although not able to prevent the incidence of hospitalization, may lead to a more rapid discharge from the hospital. The finding suggests that home and community-based care may partially substitute for inpatient hospital care, but it is unclear from our findings what specific aspect of the waiver program may have had the greatest impact on the shorter lengths of stay. A relationship that the OLS regressions did not reveal is the significantly reduced rate of transition from the hospital to death among waiver participants. This may reflect the greater ability of waiver participants to gain access to terminal-period care (such as private duty nursing) at home and thus to avoid dying in the hospital. Bivariate comparisons (not shown) indicate that decedent waiver participants were less likely to be hospitalized during the last 60 days of life than nonwaiver participants (69.3 percent versus 77.0 percent) and that they used fewer hospital days in that time period (13.7 versus 19.6 days).

Conforming to our expectations and our results from the regression models, more severely ill patients as measured by higher levels of the severity index variable had decreased rates of transition between the hospital and the community, implying longer stays. Higher severity was also associated with a higher rate of in-hospital death. There were no significant gender differences in hazard of hospital admission, discharge to the community, or death during a hospitalization. African Americans and Hispanics did not differ from non-Hispanic whites in either the hazard of transition from the hospital to the community or from the hospital to death. African Americans and Hispanics

Table 4: Three-State Multi-Episode Weibull Hazard Model of Transitions Between Hospital and Community, and Mortality ($n = 1{,}401$; Standard Errors in Parentheses)

Independent Variables	*Hospital to Community*	*Hospital to Death*	*Community to Hospital*	*Community to Death*
Female	0.006	0.042	0.024	−0.262**
	(0.033)	(0.071)	(0.036)	(0.133)
IDU	0.065*	−0.057	−0.029	−0.202
	(0.035)	(0.081)	(0.040)	(0.136)
African American	−0.063	−0.118	0.262***	−0.171
	(0.039)	(0.091)	(0.046)	(0.158)
Hispanic	−0.074	−0.023	0.212***	−0.179
	(0.047)	(0.113)	(0.056)	(0.195)
Age	−1.511***	−0.201	−0.588***	1.742***
	(0.150)	(0.337)	(0.167)	(0.565)
Near NYC	−0.138***	−0.083	0.114***	−0.025
	(0.035)	(0.089)	(0.040)	(0.143)
Waiver	0.185***	−0.303***	−0.035	−0.081
	(0.032)	(0.082)	(0.036)	(0.136)
Severity	−0.183***	0.084*	—	—
	(0.027)	(0.044)		
Year of Service (1989 Omitted)				
1988	0.170***	−2.166***	—	—
	(0.062)	(0.224)		
1990	0.246***	−0.007	—	—
	(0.059)	(0.222)		
1991	0.310***	0.124	—	—
	(0.060)	(0.223)		
1992	0.416***	−0.169	—	—
	(0.061)	(0.234)		
1993	0.536***	−0.535*	—	—
	(0.082)	(0.290)		
1994	0.665**	−0.340	—	—
	(0.216)	(0.471)		
Constant	−2.066***	−6.094***	−4.813***	−7.869***
	(0.092)	(0.301)	(0.092)	(0.340)
ln(alpha)	−0.066***	0.133***	−0.327***	−0.325***
	(0.012)	(0.028)	(0.013)	(0.038)

*Statistical significance at the 10% level.

**Statistical significance at the 5% level.

***Statistical significance at the 1% level.

did exhibit a higher rate of transition from the community to the hospital, indicating more frequent use of hospital services relative to whites. Injection drug users exhibited a marginally significant higher rate of exit from the hospital relative to non-IDUs, and revealed no apparent difference in the rate of hospital admission. This seems somewhat counterintuitive in that IDUs are at greater risk of housing problems and comorbidities that could delay discharge, but this finding could mean that injection drug users (an often stigmatized group) are treated less intensively for similar conditions while they are hospitalized, and that this outweighs any effect of housing problems or other socioeconomic difficulties they experience (Horner et al. 1996). It should also be noted that the surveillance category of "injection drug users" may include many individuals who have not used such drugs for years and whose care is therefore not complicated by comorbidities related to current drug use. Further, we do not control for whether or not drug users are in treatment for their addictions, which could have an effect on their utilization of inpatient services. It is also worth noting that some studies have found that IDUs with AIDS actually tend to have greater levels of informal care than homosexual men (Ettner and Weissman 1994).

Results of the transition analyses suggest, consistent with the findings in Table 3, that persons in the high-prevalence area of the state adjacent to New York City tended to have lower hospital-to-community transition rates, and that admissions were also more frequent in this area. Lengthy AIDS-related hospitalizations in the New York area have been documented previously (Hellinger 1992; Kelly, Ball, and Turner 1989). Hospitals in high-prevalence areas might have been expected to utilize hospital resources more efficiently because of their HIV-intensive case mix and therefore their level of experience with HIV care (Stone et al. 1992; Bennett, Adams, Bennett, et al. 1995). On the other hand, the resource demands of high numbers of persons with HIV in these areas as well as the high endemic level of poverty may affect access to HIV-related outpatient services and result in more reliance on inpatient services, perhaps outweighing any effects of increased efficiency resulting from experience. As seen in the OLS models, older PWAs had higher hospital-to-community transition rates but experienced less frequent hospitalizations and higher rates of transition from the community to death. The findings could imply, as Turner et al. (1994) suggested, that older PWAs had greater social resources from which they could draw support. However, further research with larger samples of older PWAs is needed in order to understand more clearly the effects of age on AIDS hospitalizations.

The results in Table 4 indicate that hazards of hospital-to-community transition declined over the 1988–1994 period, but the results are consistent with the simpler models in suggesting that most of the change took place in the earlier part of that period. Note that parameters for year of service are determined relative to 1989, because 1988 was an outlier year in which few hospitalizations and very few terminal hospitalizations occurred. The hazard of death during hospitalization appears to have declined after 1990 but was significantly different from the 1989 rate only in 1993. The hospital-to-community hazard rate exhibited slightly negative duration dependence, as the (exponentiated) Weibull shape parameter was less than 1. The hospital-to-death hazard rate showed slightly positive duration dependence, indicating that longer hospital spells were somewhat more likely to end in death than were shorter hospitalizations. The community-to-hospital and community-to-death hazard rates displayed negative duration dependence. The results suggest that PWAs with infrequent hospital admissions are less likely to re-enter the hospital than someone recently released from the hospital, although the estimates may be affected by unobserved heterogeneity in health status.

Simulated Outcomes from Estimated Parameters

The coefficient estimates in Table 4 indicate the direction of the effect associated with each covariate, but their magnitudes are not straightforward to interpret. Simulations with all other covariates set at their means, shown in Table 5, help in interpreting the implications of the parameter estimates.

The first column of Table 5 shows the predicted duration of a hospital stay. The second column shows the predicted probabilities that the hospital stay will end in death. The third column shows the predicted probability of an inpatient admission within 90 days, conditional on being in the community at a given time. For example, in the baseline scenario with all covariates set to their means, the predicted length of stay for a hospitalized person is about 16 days, the predicted probability of the stay ending in death is roughly 20 percent, and the predicted probability that a person in the community will be admitted to a hospital within a 90-day period is about 54 percent. We observe that more severely diseased patients have longer spells in the hospital: moving from the lowest AIDS severity of 1.0 to the most severe of 3.4 is associated with an increase in the mean length of stay from about 15 days to nearly 20 days. However, as severity increases, the probability that the hospitalization will be terminal nearly doubles, increasing from 17 percent to 30 percent. This reinforces previous findings of positive associations among severity, length of stay, and death rates among AIDS patients.

Table 5: Predicted Effects on Mean Length of Hospital Stay, Terminal Hospitalization Probability, and Hospital Admission Probability Within 90 Days

	Mean Length of Stay in Hospital	*Transition Probabilities*	
		$H - D^*$	$C - H^\dagger$
Baseline: Variables at Means	16.17	0.195	0.544
Severity			
1.0	15.20	0.173	–
2.0	17.16	0.219	–
3.0	19.09	0.272	–
3.4	19.84	0.295	–
Gender			
Male	16.27	0.193	0.542
Female	16.04	0.199	0.548
Race/Ethnicity			
White	15.33	0.199	0.495
African American	16.54	0.190	0.561
Hispanic	16.31	0.208	0.548
Risk Group			
Non-IDU	16.61	0.211	0.549
IDU	16.01	0.189	0.542
Region			
Near NYC	16.78	0.198	0.552
Rest of state	14.80	0.189	0.522
Waiver Status			
Non-ACCAP	16.53	0.224	0.547
ACCAP	15.25	0.145	0.538
Age			
25	13.52	0.164	0.569
35	15.94	0.193	0.549
45	18.69	0.224	0.528
55	21.77	0.258	0.508
Year of Service			
1988	22.30	0.027	–
1989	19.29	0.274	–
1990	16.23	0.223	–
1991	14.95	0.236	–
1992	14.76	0.166	–
1993	14.15	0.104	–
1994	12.33	0.112	–

Note: All independent variables except for the variable being examined were set to their mean for the purposes of constructing the predicted values.

*Predicted probability that typical hospital stay ends in death.

†Predicted probability of hospital admission within 90 days for typical respondent.

With other characteristics held constant, waiver participants had hospitalization spells 1.3 days shorter than traditional Medicaid enrollees. Their probability of dying during an "average" hospitalization was 15 percent, versus 22 percent for nonwaiver participants. As age at diagnosis increased from 25 to 55 years, the average duration of hospitalized spells increased from 13.5 days to 21.8 days. The probability that an average hospitalization would end in death was 26 percent for 55-year-olds versus 16 percent for 25-year-olds, while the probability that an individual in the community would be hospitalized within 90 days was 51 percent for 55-year-olds versus 57 percent for 25-year-olds. The simulations show that the significant effect of IDU status on length of stay noted earlier translates to a 0.6-day shorter stay for an average hospitalization, and that the significant effect of African American race or Hispanic ethnicity on frequency of admissions translates to 90-day hospitalization probabilities of 56 percent for African Americans and 55 percent for Hispanics versus 50 percent for whites. Length of stay was 2.0 days longer for a resident of the area near New York City, and mean length of stay for an average PWA decreased from 22.3 days in 1988 to 12.3 days in 1994, with most of the change occurring in the 1988–1990 period.

CONCLUSION

Many health services research studies involve the effort to understand the effect of various factors on the rate of transition from one setting to another. This is true of research on hospitalization, although few studies model hospital use in this fashion; it is also true of the use of other institutional services such as nursing homes. Frequency of admission and length of stay are usually modeled separately, but they actually reflect distinct aspects of a single process and ideally should be modeled jointly as in the present analysis. In many situations, such as interview-based studies in which the recall period is the same for all respondents, simple methods can be used to model frequency of hospitalization. However, in other situations, such as claims-based studies in which the duration of observation varies from individual to individual, or analyses in which competing risks of more than one type of event (such as hospital admission and death) are a concern, there is a need for more sophisticated analytic methods.

The three-state, multi-episode duration framework demonstrated in the analysis presented here provides a statistical representation of hospital utilization that is congruent with the nature of the hospitalization process as a series of admission and discharge events that take place over time. By focusing

on transitions between states, this framework handles duration in a natural and distributionally appropriate fashion; allows the analyst to distinguish influences on the frequency of hospitalization from influences on length of stay; and controls appropriately for death as a risk that statistically competes with the risk of hospitalization or discharge from the hospital to the community. Thus, this framework has broad applicability in studying patterns of admission and discharge transitions to and from hospitals and other healthcare facilities. It makes use of information on multiple transitions experienced by each individual without reducing the model to the hospitalization rather than the person level of analysis, and it provides for simultaneous estimation of the hazards of transitions to and from inpatient and in-community spells. This statistically efficient approach reduces important biases that plague simpler models; makes the best use of continuous-time data that permit classification of each individual's status on a given day as hospitalized or in the community; and is applicable to a broad range of problems in health services research.

Substantively, this transition analysis shows that participation in a Medicaid waiver program was associated with shorter hospital stays and a lower probability of death while hospitalized. Gender differences were of special interest because prior studies had varied widely in their estimates of gender effects. For example, Hellinger (1993) reported that women use fewer hospital services than men; other studies found few gender differences in the use of hospital services (Kelly, Ball, and Turner 1989; Seage et al. 1993; Fleishman, Hsia, and Hellinger 1994); and still others reported that women with AIDS experience more hospitalization (Fleishman, Mor, and Laliberte 1995). In our study, no gender effect on the incidence or length of hospitalization was found. There was also no gender difference in the rate of death during hospitalizations. This is in contrast to the finding by Bastian, Bennett, and Sloane (1994) that among individuals hospitalized with pneumocystis carinii pneumonia, and adjusting for severity, women were significantly more likely than men to die in the hospital (26 percent versus 17 percent, $p = .05$), a finding that they attributed to differences in the level of quality of care received in the hospital. In our study population, however, for the full range of diagnoses, there were no apparent gender differences in mortality, frequency, or duration of hospital stays.

However, there were other subgroup differences in the use of inpatient care. African American race and Hispanic ethnicity were both associated with more frequent hospitalization. Strong regional differences also appeared within the state, with high-prevalence counties near New York City exhibiting both longer stays and more frequent admissions. This is the most urbanized

area of New Jersey, with high poverty rates. The regional differences may involve HIV-specific issues, such as higher HIV caseloads, a heavier burden on HIV outpatient services, and difficulty in achieving access to outpatient regional care, or it may reflect general regional differences in patterns of hospital care that affect length of stay for other diseases as well. At the mean for other variables, residence in this area of the state was associated with a two-day increase in length of stay. The effects of age were substantial, with older respondents hospitalized less often but for longer periods. With other variables at their means, length of stay was estimated at 21.7 days for a 55-year-old person in contrast to 13.5 days for a respondent 25 years old. Overall length of hospitalizations declined over time, although most of the observed change appears to have taken place before 1992. The simulations indicate that at the mean for other variables, waiver participation was associated with a 1.28-day reduction in length of stay. In addition, waiver enrollees appeared to have a lower rate of terminal hospitalization than PWAs not enrolled in the waiver program.

Several caveats need to be noted. Our study sample resided in only one state and included only Medicaid participants. However, New Jersey is a diverse state encompassing urban, suburban, and rural areas, and Medicaid is the predominant payer for AIDS-related care in the state. To reduce bias from left-censoring, we focused on the population enrolled in Medicaid throughout the period from diagnosis to death or censoring, who might differ from other Medicaid PWAs (Weissman, Cleary, Seage, et al. 1996), although we attempted to address this possibility with sensitivity analyses. The relatively long hospital stays we observed may be less typical in other areas of the country (Horner, Bennett, Achenbach, et al. 1996). Hospitalization rates have recently declined as a result of the introduction of highly active antiretroviral therapy, or HAART, typically involving a protease inhibitor (Mouton, Alfandari, Valette, et al. 1997; Torres and Barr 1997; Palella, Delaney, Moorman, et al. 1998). Thus, the frequency of admissions observed in this study is probably higher than that which is currently prevalent. However, unless these new therapies improve enough to induce permanent remissions of HIV disease, they will postpone but not prevent the eventual need for inpatient hospitalization as immunosuppression progresses; therefore, it continues to be important to understand patterns and subgroup differences in hospital use. Event history methods such as those described in this article will be useful in future analyses of hospitalizations of patients with HIV disease, as well as in studies on other chronic diseases in which patients have repeated hospital admissions.

Despite these caveats, our analyses provide an important perspective on AIDS-related hospitalization by examining the full extent of inpatient utilization histories among a demographically diverse, statewide population of AIDS patients, including the terminal period of illness. Within this population, substantial subgroup and geographic differences were found to exist in both the frequency of hospitalization and its duration. Despite the relatively high level of HIV experience among hospitals in the high-prevalence area of the state, PWAs in this area experienced stays that were more frequent and longer than those experienced elsewhere. PWAs in the home and community-based waiver program experienced shorter hospitalizations, perhaps because timely discharges were facilitated by the availability of post-acute care as a result of the case management and home care services available to participants. The racial difference in frequency of admission may also reflect differences in access to outpatient and community-based services. The socioeconomic and geographic differences in patterns of HIV hospitalization suggest that a variety of nonclinical factors shape HIV-related hospital use, even within a single state and payer system. In studying these patterns, it is important to distinguish between differences in the incidence of hospitalization and differences in its duration, because these two aspects of the hospitalization process do not necessarily covary. Event history analysis provides a useful statistical framework for analysis of these variations.

ACKNOWLEDGMENTS

The authors wish to acknowledge and thank the New Jersey Department of Human Services and the New Jersey Department of Health and Senior Services for their support and provision of data extracts for this research. We also thank two anonymous referees for *Health Services Research* for their helpful suggestions on an earlier version of this article.

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