Appendix A

1. Review of the Cox Proportional Hazards model for survival analysis

In this section we provide a brief review of the Cox proportional hazards model for the analysis of survival data. The use of this model is ubiquitous in many research fields. We introduce this model as it forms the basis for one of the methods for the analysis of multilevel survival data.

Let T denote the time of the occurrence of the event of interest. A key concept in survival analysis is that of the hazard function: $h(t) = \lim_{\Delta t \to 0} \frac{\Pr(t \le T < t + \Delta t \mid T \ge t)}{\Delta t}$. The hazard function is a function of time that denotes the instantaneous rate of the occurrence of the event, conditional on the subject having survived to time *t*. The Cox proportional hazard regression model relates explanatory variables to the hazard function: $h_i(t) = h_0(t)\exp(\alpha_1 X_{1i} + \cdots + \alpha_p X_{pi})$, where $h_i(t)$ denotes the hazard function for the *i*th subject, while $h_0(t)$ denotes the baseline hazard function (the hazard function for a subject whose covariates are all equal to zero). The model can also be formulated on the log-hazard scale: $\log(h_i(t)) = \log(h_0(t)) + \alpha_1 X_{1i} + \cdots + \alpha_p X_{pi}$.

Regression coefficients from the Cox proportional hazards model are log-hazard ratios. When a regression coefficient is exponentiated, it denotes the relative change in the hazard of the occurrence of the event of interest that is associated with a one unit increase in the associated predictor variable.

The reader is referred elsewhere for comprehensive background information on these models (Therneau and Grambsch 2000;Lawless 1982;Kalbfleisch and Prentice 2002;Hosmer and Lemeshow 1999;Cox and Oakes 1984;Hosmer, Lemeshow and May 2008).

2. Choosing between frailty distributions

Therneau and Grambsch provide limited advice on choosing between the gamma and log-normal distributions for the shared frailty terms (Therneau and Grambsch 2000). They note that the former distribution is asymmetric on the log-hazard scale, while the latter is symmetric. In a particular application, Therneau and Grambsch noted that the estimated gamma distribution had a heavy lower tail, implying the existence of a proportion of clusters with exceptionally low risk. Based on the setting, this assumption may or not be appropriate. If it were inappropriate, the log-normal shared frailty model may be more appropriate. Several authors have described methods for assessing whether a frailty model in which the random effects follow a gamma distribution fit the data well. We briefly highlight different methods, referring the interested reader to the summary provided by Wienke (Wienke 2011). Shih and Louis describe a graphical method for assessing the appropriateness of the gamma distribution when used with a shared frailty model (Shih and Louis 1995). However, this test is of limited applicability, as it assumes that the baseline hazard function is parametric and is known. Glidden extended these methods to develop graphical and numerical methods for assessing the adequacy of the assumption that the shared frailty terms follow a gamma distribution (Glidden 1999). His method was based on the posterior expectation of the frailty given the observed data. Finally, Cui and Sun developed similar graphic and numerical methods for assessing the goodness-of-fit of the gamma frailty model (Cui and Sun 2004). However, a limitation of each of these methods is that they do not allow for the comparison between different distributions for the shared frailty terms, but only permit an assessment of whether the gamma distribution is reasonable. Therneau expressed a preference for the log-normal distribution for the random effects as this leads to a simpler framework for multiple and correlated random effects (Therneau 2015). Chateau and Janssen suggest that further research in this area is required (Duchateau and Janssen 2008).

3. Variable names in case study

In the software output that is provided, the following variable names are used for patient-level variables: age (patient age), female (patient sex: males are the reference category), arf (acute renal failure), carddys (cardiac dysrhythmia), chf (congestive heart failure), crf (chronic renal failure), cvd (cerebrovascular disease or stroke), diabcomp (diabetes mellitus with complications), malig (malignancy), pulmoned (pulmonary edema), shock (cardiogenic shock). The variable ‘inst’ (short for institution) is a variable denoting the identity of the hospital to which the patient was admitted. The hospital-level variables are as follows: instvolume (hospital AMI volume in year prior to study), teachinghosp (teaching vs. non-teaching hospital), hosprevasc (capacity for cardiac revascularization at the hospital), hospcath (capacity for cardiac angiography at the hospital). When fitting PWE mixed effects models or discrete time mixed effects models, ‘interval’ is a variable denoting the time interval to which the record in question refers. When fitting the PWE mixed effects models, ‘logtime’ is an offset variable denoting the logarithm of the exposure time during the given interval.

4. Comparison of statistical software packages for analyzing multilevel survival data

Software package	Advantages	Disadvantages
R	• Cox-mixed effects model can incorporate random coefficients (using the coxme and frailtypack packages). • Cox-mixed effects model can incorporate multiple random effects, allowing for the analysis of multilevel data with more than two levels (using the coxme and frailtypack packages) • Cox-frailty model fit using `coxph` function in survival package allows two different distributions for the shared frailty terms (gamma and log-normal distributions). • The `survSplit` function in the	• glmer function in lme4 package for estimating the PWE and discrete time survival model is restricted to one estimation method (adaptive Gauss-Hermite quadrature). However, it does permit specification of the number of quadrature points (the use of one quadrature point is equivalent to using the Laplace approximation to the log-likelihood).

	survival package can be used in the construction of the datasets for the PWE and discrete time survival models.	
SAS	• Cox-frailty model fit using PHREG procedure allows two different distributions for the shared frailty terms (gamma and log-normal). • Proc GLIMMIX, used for fitting the PWE model with mixed effects and discrete time model with mixed effects, has a large number of estimation method implemented.	• Requires using programming steps to create datasets for the PWE and discrete time survival models. • Cox model with mixed effects cannot incorporate random coefficients. • Cox model with mixed effects cannot analyze multilevel data with more than two levels.
Stata	• The `stsplit` function can be used in the construction of the datasets for the	• Cox-frailty model fit only allows one distribution for the shared

	PWE and discrete time survival models. • The mepoisson function for fitting the PWE survival model with mixed effects has a large number of estimation method implemented. • The mecloglog function for fitting the discrete time survival model with mixed effects has a large number of estimation method implemented.	frailty terms (gamma distribution). • Cox model with mixed effects cannot incorporate random coefficients. • Cox model with mixed effects cannot analyze multilevel data with more than two levels.

Appendix B. Statistical software code for fitting two-level multilevel survival models.

Statistical software code 1: SAS code for frailty survival model (log-normal frailty distribution)

```
proc phreg data=cohort;
  class inst;
  model time*event(0) = age female arf carddys chf crf
    cvd diabcomp malig pulmoned shock instvolume teachinghosp
    hosprevasc hospcath /ties=efron;
  random inst /dist=lognormal;
run;
```

Statistical software code 2: SAS code for frailty survival model (Gamma distribution)

```
proc phreg data=cohort;
  class inst;
  model time*event(0) = age female arf carddys chf crf
    cvd diabcomp malig pulmoned shock instvolume teachinghosp
    hosprevasc hospcath /ties=efron;
  random inst /dist=gamma;
run;
```

Statistical software code 3: R code for frailty survival model (log-normal frailty distribution)

```
Model.frailty.gaussian <- coxph(Surv(time,event) ~ age + female + arf +
  carddys + chf + crf + cvd + diabcomp + malig + pulmoned + shock +
  instvolume + teachinghosp + hosprevasc + hospcath +
  frailty(inst,distribution="gaussian"), data=omid)
```

Statistical software code 4: R code for frailty survival model (Gamma distribution)

```
Model.frailty.gamma <- coxph(Surv(time,event) ~ age + female + arf +
  carddys + chf + crf + cvd + diabcomp + malig + pulmoned + shock +
  instvolume + teachinghosp + hosprevasc + hospcath +
  frailty(inst,distribution="gamma"), data=omid)
```

Statistical software code 5: Stata code for frailty survival model (Gamma distribution)

```
stset time, failure(event)
# Declares data to be survival data

stcox age female arf carddys chf crf cvd diabcomp malig pulmoned shock
instvolume teachinghosp hosprevasc hospcath, efron shared(inst)
```

Statistical software code 6: SAS code for PWE survival model with mixed effects

```
proc glimmix data=omid2 method=quad(qpoints=7);
  class inst interval;
  model event = age female arf carddys chf crf cvd
    diabcomp malig pulmoned shock instvolume teachinghosp
    hosprevasc hospcath interval /dist=poisson offset=logtime
    solution;
```

```
  random intercept /subject = inst;
run;
```

Statistical software code 7: R code for PWE survival model with mixed effects

```
glmer(event ~ age + female + arf + carddys + chf + crf + cvd +
  diabcomp + malig + pulmoned + shock + instvolume + teachinghosp +
  hosprevasc + hospcath + interval + (1|inst),family=poisson,
  offset=logtime,nAGQ=7,data=omid2)
```

Statistical software code 8: Stata code for PWE survival model with mixed effects

```
mepoisson event age female arf carddys chf crf cvd diabcomp malig
pulmoned shock instvolume teachinghosp hosprevasc hospcath i.interval,
intmethod(mcaghermite) intpoints(7) offset(logtime) || inst:
```

Statistical software code 9: SAS code for discrete time survival model with mixed effects

```
proc glimmix data=cohort2 method=quad(qpoints=7);
  class inst interval;
  model event = age female arf carddys chf crf cvd
    diabcomp malig pulmoned shock instvolume teachinghosp
    hosprevasc hospcath interval /dist=binomial link=cloglog
      solution;
  random intercept /subject = inst;
run;
```

Statistical software code 10: R code for discrete time survival model with mixed effects

```
glmer(event ~ age + female + arf + carddys + chf + crf + cvd +
  diabcomp + malig + pulmoned + shock + instvolume + teachinghosp +
  hosprevasc + hospcath + interval +
  1|inst),family=binomial(link="cloglog"),nAGQ=7,data=omid2)
```

Statistical software code 11: Stata code for discrete time survival model with mixed effects

```
mecloglog event age female arf carddys chf crf cvd diabcomp malig
pulmoned shock instvolume teachinghosp hosprevasc hospcath i.interval,
intmethod(mcaghermite) intpoints(7) || inst:
```

Statistical software code 12: SAS code for discrete time survival model with random coefficients (effect of shock varies across hospitals)

```
proc glimmix data=cohort2 method=quad(qpoints=7);
  class inst interval;
  model event = age female arf carddys chf crf cvd
    diabcomp malig pulmoned shock instvolume teachinghosp
    hosprevasc hospcath interval /dist=binomial link=cloglog solution;
  random intercept shock /subject = inst;
run;
```

Statistical software code 13: R code for Cox model with random coefficients (effect of shock varies across hospitals)

```
coxme(Surv(time,event) ~ age + female + arf + carddys + chf + crf +
  cvd + diabcomp + malig + pulmoned + shock + instvolume +
  teachinghosp + hosprevasc + hospcath + (1 + shock|inst),
  ties="efron", data=omid)
```

Statistical software code 14: SAS code for log-normal frailty survival model with cross-level interactions

```
proc phreg data=cohort;
  class inst;
  model time*event(0) = age female arf carddys chf crf
    cvd diabcomp malig pulmoned shock instvolume teachinghosp
    hosprevasc hospcath shock*hosprevasc shock*hospcath f/ties=efron;
  random inst /dist=lognormal;
run;
```

Statistical software code 15: SAS code for discrete time survival model with mixed effects and with cross-level interactions

```
proc glimmix data=cohort2 method=quad(qpoints=7);
  class inst interval;
  model event = age female arf carddys chf crf cvd
    diabcomp malig pulmoned shock instvolume teachinghosp
    hosprevasc hospcath shock*hosprevasc shock*hospcath interval
    /dist=binomial link=cloglog solution;
  random intercept /subject = inst;
run;
```

Appendix C. Two-level multilevel survival models: Output of select statistical analyses.

Statistical software output C1: SAS output for frailty survival model (gamma distribution)

Covariance Parameter Estimates

Cov Parm	Estimate
inst	0.02443

Analysis of Maximum Likelihood Estimates

Parameter	DF	Parameter Estimate	Standard Error	Chi-Square	Pr > ChiSq
age	1	0.06105	0.00223	751.7272	<.0001
female	1	0.10177	0.04537	5.0323	0.0249
arf	1	0.45370	0.06935	42.8057	<.0001
carddys	1	0.11369	0.05526	4.2328	0.0396
chf	1	0.22287	0.04817	21.4093	<.0001
crf	1	0.22583	0.07056	10.2428	0.0014
cvd	1	0.36860	0.10433	12.4831	0.0004
diabcomp	1	0.24469	0.08794	7.7425	0.0054
malig	1	0.91116	0.08811	106.9296	<.0001
pulmoned	1	0.15493	0.18017	0.7395	0.3898
shock	1	2.09449	0.08149	660.6722	<.0001
instvolume	1	-0.0006060	0.0002580	5.5189	0.0188
teachinghosp	1	-0.16025	0.08820	3.3012	0.0692
hosprevasc	1	0.12690	0.08440	2.2610	0.1327
hospcath	1	-0.18301	0.15061	1.4764	0.2243

Statistical software output C2: R output for frailty survival model (log-normal frailty distribution)

```
                          coef      se(coef) se2      Chisq  DF   p      
age                        0.061068 0.002228 0.002222 751.27  1.0 0.0e+00
female                     0.101635 0.045387 0.045282   5.01  1.0 2.5e-02
arf                        0.453468 0.069418 0.069057  42.67  1.0 6.5e-11
carddys                    0.114358 0.055286 0.055127   4.28  1.0 3.9e-02
chf                        0.223574 0.048193 0.048052  21.52  1.0 3.5e-06
crf                        0.226253 0.070611 0.070368  10.27  1.0 1.4e-03
cvd                        0.368083 0.104421 0.104059  12.43  1.0 4.2e-04
diabcomp                   0.245576 0.088015 0.087644   7.79  1.0 5.3e-03
malig                      0.912190 0.088164 0.087892 107.05  1.0 0.0e+00
pulmoned                   0.152244 0.180309 0.179722   0.71  1.0 4.0e-01
shock                      2.092748 0.081617 0.080954 657.46  1.0 0.0e+00
instvolume                -0.000635 0.000264 0.000213   5.77  1.0 1.6e-02
teachinghosp              -0.163355 0.092080 0.067756   3.15  1.0 7.6e-02
hosprevasc                 0.125466 0.087971 0.061652   2.03  1.0 1.5e-01
hospcath                  -0.177201 0.157116 0.115715   1.27  1.0 2.6e-01
frailty(inst, distributio                              53.26 34.2 2.0e-02

Iterations: 9 outer, 42 Newton-Raphson
     Variance of random effect= 0.0295
```

Statistical software output C3: R output for frailty survival model (Gamma distribution)

```
                          coef      se(coef) se2     Chisq  DF   p
age                        0.061050 0.002227 0.00222 751.70  1.0 0.0e+00
female                     0.101772 0.045370 0.04527   5.03  1.0 2.5e-02
arf                        0.453702 0.069351 0.06900  42.80  1.0 6.1e-11
carddys                    0.113699 0.055260 0.05511   4.23  1.0 4.0e-02
chf                        0.222883 0.048169 0.04804  21.41  1.0 3.7e-06
crf                        0.225835 0.070564 0.07033  10.24  1.0 1.4e-03
cvd                        0.368589 0.104331 0.10398  12.48  1.0 4.1e-04
diabcomp                   0.244699 0.087942 0.08758   7.74  1.0 5.4e-03
malig                      0.911175 0.088117 0.08786 106.93  1.0 0.0e+00
pulmoned                   0.154896 0.180172 0.17962   0.74  1.0 3.9e-01
shock                      2.094482 0.081495 0.08086 660.53  1.0 0.0e+00
instvolume                -0.000606 0.000256 0.00021   5.63  1.0 1.8e-02
teachinghosp              -0.160310 0.088516 0.06726   3.28  1.0 7.0e-02
hosprevasc                 0.126950 0.084779 0.06177   2.24  1.0 1.3e-01
hospcath                  -0.182991 0.150976 0.11587   1.47  1.0 2.3e-01
frailty(inst, distributio                             47.53 30.5 2.5e-02

Iterations: 8 outer, 43 Newton-Raphson
     Variance of random effect= 0.0245   I-likelihood = -19370.5
```

Statistical software output C4: Stata output for frailty survival model (Gamma distribution)

_t	Haz. Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
age	1.064749	.002585	25.84	0.000	1.059695	1.069828
female	1.071057	.0523427	1.40	0.160	.9732274	1.178721
arf	1.717356	.1250196	7.43	0.000	1.489	1.980732
carddys	1.133844	.0669874	2.13	0.033	1.009867	1.27304
chf	1.404549	.0719032	6.64	0.000	1.270461	1.55279
crf	1.252364	.0939461	3.00	0.003	1.081129	1.450719
cvd	1.367561	.157352	2.72	0.007	1.091459	1.713509
diabcomp	1.330236	.1228782	3.09	0.002	1.109943	1.594252
malig	2.497872	.2357743	9.70	0.000	2.07599	3.005489
pulmoned	1.140032	.2274025	0.66	0.511	.7711302	1.685414
shock	6.0303	.6095204	17.78	0.000	4.946553	7.351488
instvolume	.9994406	.000274	-2.04	0.041	.9989037	.9999777
teachinghosp	.8506432	.0789609	-1.74	0.081	.7091444	1.020376
hosprevasc	1.105139	.098285	1.12	0.261	.9283587	1.315583
hospcath	.8281011	.1314021	-1.19	0.235	.6067583	1.130189
theta	.0254732	.0122412				

Statistical software output C5: R output for PWE survival model with mixed effects

```
Random effects:
 Groups Name        Variance Std.Dev.
 inst   (Intercept) 0.02563  0.1601
Number of obs: 79653, groups:  inst, 164

Fixed effects:
               Estimate Std. Error z value Pr(>|z|)
(Intercept)  -4.6872737  0.0607007  -77.22  < 2e-16 ***
age           0.0613924  0.0022291   27.54  < 2e-16 ***
female        0.1013090  0.0453745    2.23 0.025567 *
arf           0.4582970  0.0694099    6.60 4.04e-11 ***
carddys       0.1130633  0.0552998    2.04 0.040899 *
chf           0.2226240  0.0482294    4.62 3.91e-06 ***
crf           0.2234466  0.0706464    3.16 0.001562 **
cvd           0.3688316  0.1043588    3.53 0.000409 ***
diabcomp      0.2459027  0.0880226    2.79 0.005212 **
malig         0.9179610  0.0881876   10.41  < 2e-16 ***
pulmoned      0.1514139  0.1803052    0.84 0.401040
shock         2.1181020  0.0815805   25.96  < 2e-16 ***
instvolume   -0.0006135  0.0002657   -2.31 0.020948 *
teachinghosp -0.1599794  0.0896200   -1.79 0.074248 .
hosprevasc    0.1236705  0.0850027    1.45 0.145697
hospcath     -0.1798377  0.1522721   -1.18 0.237591
interval2    -0.4812075  0.0591985   -8.13 4.34e-16 ***
interval3    -1.1440495  0.0630744  -18.14  < 2e-16 ***
interval4    -2.0116903  0.0677953  -29.67  < 2e-16 ***
interval5    -2.5240312  0.0823414  -30.65  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Statistical software output C6: SAS output for PWE survival model with mixed effects

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error
Intercept	inst	0.02578	0.01187

Solutions for Fixed Effects

Effect	interval	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept		-7.1881	0.08321	159	-86.39	<.0001
age		0.06148	0.002230	79474	27.58	<.0001
female		0.09703	0.04537	79474	2.14	0.0325
arf		0.4556	0.06942	79474	6.56	<.0001
carddys		0.1140	0.05528	79474	2.06	0.0392
chf		0.2218	0.04823	79474	4.60	<.0001
crf		0.2253	0.07057	79474	3.19	0.0014
cvd		0.3678	0.1044	79474	3.52	0.0004
diabcomp		0.2516	0.08784	79474	2.86	0.0042
malig		0.9275	0.08785	79474	10.56	<.0001
pulmoned		0.1586	0.1796	79474	0.88	0.3772
shock		2.1229	0.08141	79474	26.08	<.0001
instvolume		-0.00061	0.000266	79474	-2.30	0.0213
teachinghosp		-0.1654	0.08989	79474	-1.84	0.0658
hosprevasc		0.1346	0.08531	79474	1.58	0.1147
hospcath		-0.1896	0.1526	79474	-1.24	0.2142
interval	1	2.5008	0.08159	79474	30.65	<.0001
interval	2	2.0143	0.08336	79474	24.16	<.0001
interval	3	1.3525	0.08607	79474	15.72	<.0001
interval	4	0.4848	0.08954	79474	5.41	<.0001
interval	5	0	.	.	.	.

Statistical software output C7: SAS output for discrete time survival model with mixed effects

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error
Intercept	inst	0.02258	0.01099

Solutions for Fixed Effects

Effect	interval	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept		-4.8779	0.08300	159	-58.77	<.0001
age		0.06065	0.002218	79474	27.35	<.0001
female		0.09751	0.04530	79474	2.15	0.0314
arf		0.4575	0.06944	79474	6.59	<.0001
carddys		0.1042	0.05536	79474	1.88	0.0597
chf		0.2203	0.04817	79474	4.57	<.0001
crf		0.2207	0.07077	79474	3.12	0.0018
cvd		0.3684	0.1042	79474	3.54	0.0004
diabcomp		0.2343	0.08830	79474	2.65	0.0080
malig		0.9020	0.08839	79474	10.20	<.0001
pulmoned		0.1736	0.1787	79474	0.97	0.3312
shock		2.0700	0.08177	79474	25.31	<.0001
instvolume		-0.00056	0.000258	79474	-2.15	0.0314
teachinghosp		-0.1211	0.08629	79474	-1.40	0.1604
hosprevasc		0.09188	0.08229	79474	1.12	0.2642
hospcath		-0.1881	0.1484	79474	-1.27	0.2051
interval	1	0.9015	0.08198	79474	11.00	<.0001
interval	2	0.8203	0.08369	79474	9.80	<.0001
interval	3	0.6749	0.08636	79474	7.81	<.0001
interval	4	0.5003	0.08980	79474	5.57	<.0001
interval	5	0	.	.	.	.

Statistical software output C8: Stata output for discrete time survival model with mixed effects

event	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
event						
age	.0610397	.0022284	27.39	0.000	.056672	.0654073
female	.0994398	.0454	2.19	0.029	.0104575	.1884221
arf	.4601694	.069451	6.63	0.000	.324048	.5962909
carddys	.111655	.0553444	2.02	0.044	.0031819	.2201281
chf	.2264424	.0482233	4.70	0.000	.1319264	.3209583
crf	.2275029	.0707159	3.22	0.001	.0889022	.3661035
cvd	.3658533	.1044315	3.50	0.000	.1611713	.5705352
diabcomp	.2461317	.0880711	2.79	0.005	.0735156	.4187478
malig	.9141063	.0882629	10.36	0.000	.7411141	1.087098
pulmoned	.1518741	.180534	0.84	0.400	-.2019661	.5057143
shock	2.067695	.0819378	25.23	0.000	1.9071	2.228291
instvolume	-.0006107	.0002647	-2.31	0.021	-.0011295	-.0000919
teachinghosp	-.1623565	.0892363	-1.82	0.069	-.3372564	.0125434
hosprevasc	.1234783	.0846026	1.46	0.144	-.0423397	.2892964
hospcath	-.1757588	.1516416	-1.16	0.246	-.4729709	.1214533
interval						
2	-.0806473	.0592566	-1.36	0.174	-.1967881	.0354935
3	-.2257341	.0631262	-3.58	0.000	-.3494592	-.1020091
4	-.4001375	.0678462	-5.90	0.000	-.5331135	-.2671615
5	-.9085649	.0823858	-11.03	0.000	-1.070038	-.7470917
_cons	-3.99642	.0606353	-65.91	0.000	-4.115263	-3.877577
var(_cons[~)						
_cons	.0250974	.0116899	2.15	0.032	.0021857	.0480091

Statistical software output C9: R output for Cox model with random coefficients (effect of shock varies across hospitals)

```
Model:  Surv(time, event) ~ age + female + arf + carddys + chf + crf +
cvd + diabcomp + malig + pulmoned + shock + instvolume +
teachinghosp + hosprevasc + hospcath + (1 + shock | inst)
Fixed coefficients
                      coef exp(coef)     se(coef)     z       p
age           0.0612600211 1.0631753 0.0022456404 27.28 0.0e+00
female        0.0922776608 1.0966693 0.0457531282  2.02 4.4e-02
arf           0.4685477395 1.5976723 0.0705404406  6.64 3.1e-11
carddys       0.1134615028 1.1201488 0.0555123428  2.04 4.1e-02
chf           0.2340422878 1.2636979 0.0484928814  4.83 1.4e-06
crf           0.2541525878 1.2893685 0.0711947421  3.57 3.6e-04
cvd           0.3778429460 1.4591338 0.1063291735  3.55 3.8e-04
diabcomp      0.2584206164 1.2948834 0.0883992221  2.92 3.5e-03
malig         0.9170694972 2.5019477 0.0886933944 10.34 0.0e+00
pulmoned      0.2237470480 1.2507546 0.1825727201  1.23 2.2e-01
shock         2.2445625015 9.4362863 0.1299895355 17.27 0.0e+00
instvolume   -0.0006329452 0.9993673 0.0002600221 -2.43 1.5e-02
teachinghosp -0.1376928447 0.8713663 0.0881121540 -1.56 1.2e-01
hosprevasc    0.0987517550 1.1037923 0.0834460160  1.18 2.4e-01
hospcath     -0.2186464121 0.8036058 0.1503188110 -1.45 1.5e-01

Random effects
 Group Variable  Std Dev     Variance    Corr
 inst  Intercept  0.18494547  0.03420483 -0.58184337
       shock      0.75917974  0.57635387
```

Statistical software output C10: SAS output for discrete time mixed effects model with cross-level interactions (interaction between shock and hospital capacity for invasive cardiac procedures)

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error
Intercept	inst	0.02462	0.01168

Solutions for Fixed Effects

Effect	interval	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept		-4.8883	0.08359	159	-58.48	<.0001
age		0.06121	0.002233	79472	27.42	<.0001
female		0.09317	0.04541	79472	2.05	0.0402
arf		0.4579	0.06961	79472	6.58	<.0001
carddys		0.1049	0.05551	79472	1.89	0.0589
chf		0.2228	0.04829	79472	4.61	<.0001
crf		0.2282	0.07094	79472	3.22	0.0013
cvd		0.3675	0.1045	79472	3.52	0.0004
diabcomp		0.2272	0.08869	79472	2.56	0.0104
malig		0.9117	0.08873	79472	10.28	<.0001
pulmoned		0.1658	0.1792	79472	0.93	0.3548
shock		2.0748	0.1051	79472	19.73	<.0001
instvolume		-0.00057	0.000264	79472	-2.18	0.0293
teachinghosp		-0.1261	0.08805	79472	-1.43	0.1522
hosprevasc		0.08414	0.08632	79472	0.97	0.3297
hospcath		-0.1316	0.1536	79472	-0.86	0.3918
interval	1	0.8971	0.08216	79472	10.92	<.0001
interval	2	0.8172	0.08386	79472	9.74	<.0001
interval	3	0.6727	0.08653	79472	7.77	<.0001
interval	4	0.4988	0.08998	79472	5.54	<.0001
interval	5	0	.	.	.	.
shock*hosprevasc		0.06069	0.1678	79472	0.36	0.7176
shock*hospcath		-0.7934	0.5259	79472	-1.51	0.1314