

Algorithm for detecting Acute Kidney Injury (AKI) based on serum creatinine changes with time

This algorithm relates to the NHS England patient safety alert: NHS/PSA/D/2014/010

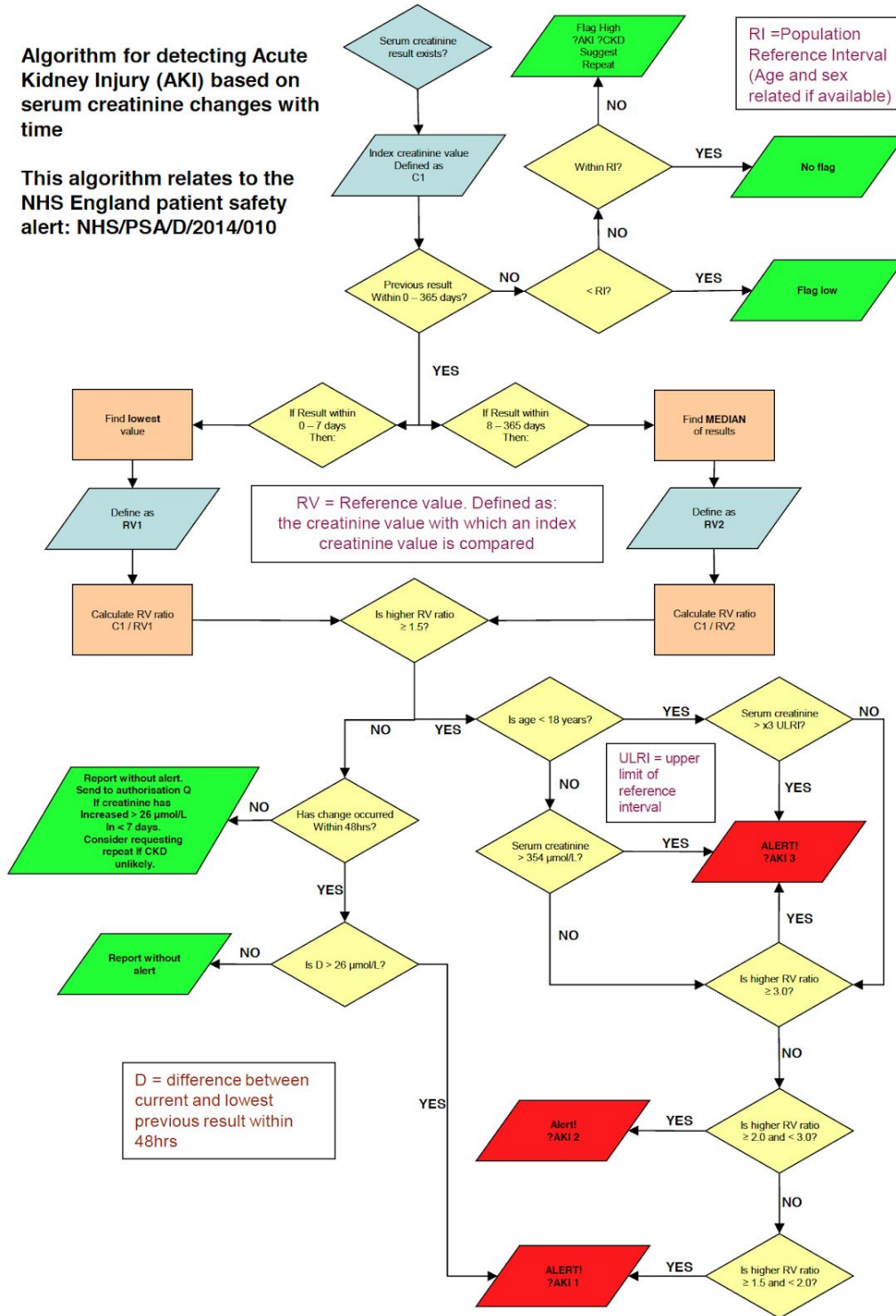


Figure 1: the NHS Early Detection Algorithm (NHSEDA)

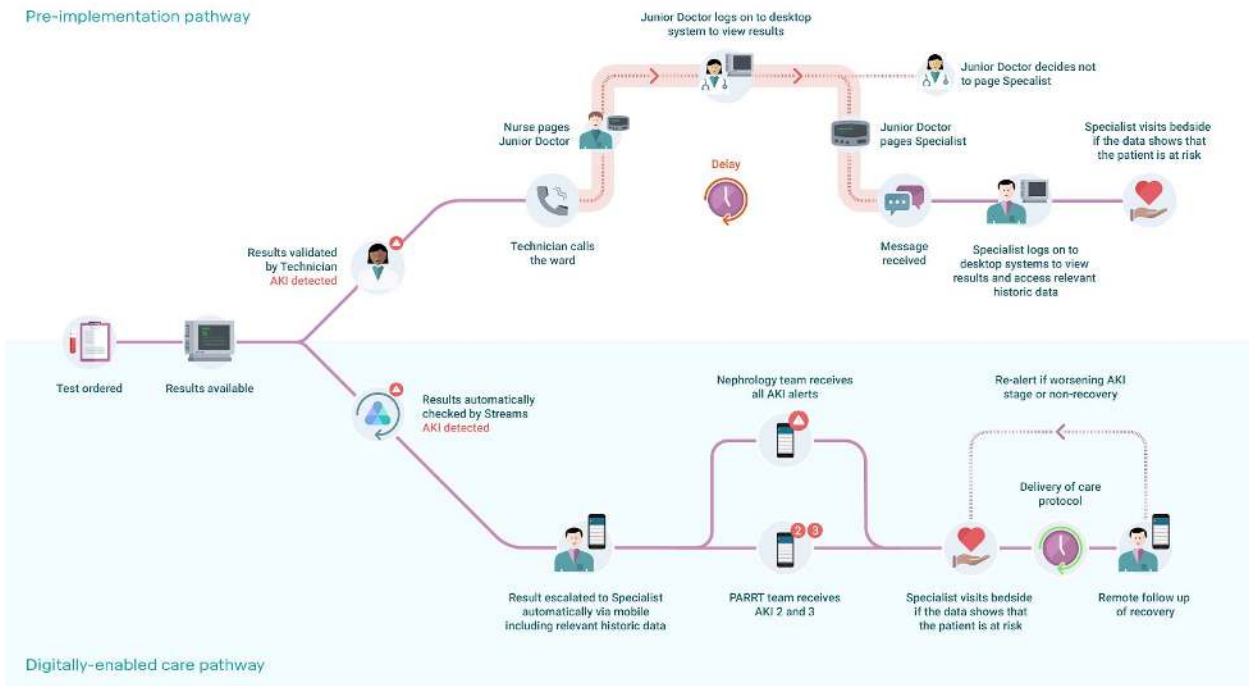



Figure 2: AKI care pathways before and after the introduction of the digitally-enabled care pathway



This patient has generated an AKI alert on the Streams application.
 The AKI response team are here to support and advise.
 Ongoing management remains the responsibility of the home team unless otherwise agreed.

affix patient sticker here

We recommend the following actions to STOP-AKI:

Management of life threatening complications of AKI	Critically ill: Call PARRT (2525) or ITU (1030)	<input type="checkbox"/>
	Hyperkalaemia or acidosis: commence medical therapy as per guidelines	<input type="checkbox"/>
	Fluid overload: Commence diuretics, nitrates/oxygen (if necessary), fluid restriction	<input type="checkbox"/>
Sepsis and hypoperfusion	Sepsis: complete Sepsis 6 care bundle	<input type="checkbox"/>
	Has an infection causing AKI: send cultures, commence or escalate antibiotics	<input type="checkbox"/>
	Hypovolaemic: Start bolus fluid protocol. Give 500mls crystalloid and reassess, repeat as necessary. Escalate to senior review after 2 litres bolus therapy	<input type="checkbox"/>
	Commence maintenance IV fluids	<input type="checkbox"/>
Toxicity	Drug cessation or adjustment required	<input type="checkbox"/>
Obstruction	Obstruction is possible and patient needs same day diagnostic renal USS Please call Matteo Rossi for bedside USS on 07443101848. If out of hours then discuss with radiology (1462). If obstruction present please contact urology registrar on 1487 or on x39536	<input type="checkbox"/>
Primary Renal Disease	Perform urine dipstick	<input type="checkbox"/>
	If urine dip clear: order 'AKI diagnostic set (basic)' on Cerner	<input type="checkbox"/>
	If blood or protein present: order 'AKI diagnostic set (glomerular)' on Cerner	<input type="checkbox"/>
General advice	<p>If in doubt, contact the AKI registrar on 07950860822 (day) or 07950843257 (night)</p> <p>For guidelines and education, visit londonaki.net or download the London AKI app:</p>  <ul style="list-style-type: none"> - Take 4 hourly observations & ensure an escalation plan is in place - Commence a fluid balance chart, measure weights daily and set a daily fluid balance target - Daily bloods: use 'AKI follow up' order set on Cerner and follow up to renal recovery - Avoid contrast if possible. Consider prophylaxis where contrast absolutely necessary - If renal function does not return to baseline at discharge, contact AKI registrar for advice 	
Follow up	We will only see if contacted by you or re-alerted in Streams due to worsening AKI	<input type="checkbox"/>
	We will schedule a further review	<input type="checkbox"/>
	We will take over care of patient	<input type="checkbox"/>

TIME SEEN: _____; _____ DATE: ____/____/____ SIGNED: _____

Grade: Registrar Consultant NAME: _____

Figure 3: the care protocol

This patient has developed acute kidney injury (AKI)

You need to do the following to help your patient recover:



Do a urine dipstick



Start 4 hourly observations



Start a fluid balance chart

Ensure prescribed oral or intravenous fluid is administered.
Document inputs/ outputs/ 24 hour fluid balance and weight.



Escalate concerns

If concerned, get help. Call the medical team, and PARRT (2525).

Figure 4: nursing advisory sticker

	Operator 1	Operator 2
Operator 1	$\kappa = 0.83$ (0.76 - 0.90)	
Operator 2	$\kappa = 0.75$ (0.65 - 0.84)	$\kappa = 0.79$ (0.71 - 0.87)

Table 1: Inter- and intra-operator variability analyses

From the pool of alerts, a random selection of 250 from each operator were validated again by both. For each comparison pair, Cohen's kappa coefficient was calculated to establish inter- and intra-operator variability. 95% confidence intervals are shown in brackets

Chair

Prof. Kevin Moore

Professor of Hepatology, Royal Free Hospital

Patient representative

Michael Wise

Acute Kidney Injury National Programme Board

External members

Sir Nick Black

Professor of Health Services Research, London School of Hygiene and Tropical Medicine

Dr. Neil Ashman

Consultant Nephrologist and Deputy Managing Director, Barts Health

Royal Free Hospital Members

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Consultant in Intensive Care Medicine

Dr. Nick Murch

Consultant in Acute Medicine

Dr. Jonathan Costello

Clinical Director, Emergency Medicine

Dr. Bimbi Fernando

Consultant in Transplant Surgery

Dr. Penny Smith

Consultant in Acute Medicine and Chief Medical Informatics Officer

Dr. Banwari Agarwal

Consultant in Intensive Care Medicine

Dr. Rupert Negus

Consultant in Acute Medicine and Gastroenterology

Figure 5: RFH Data Monitoring Committee

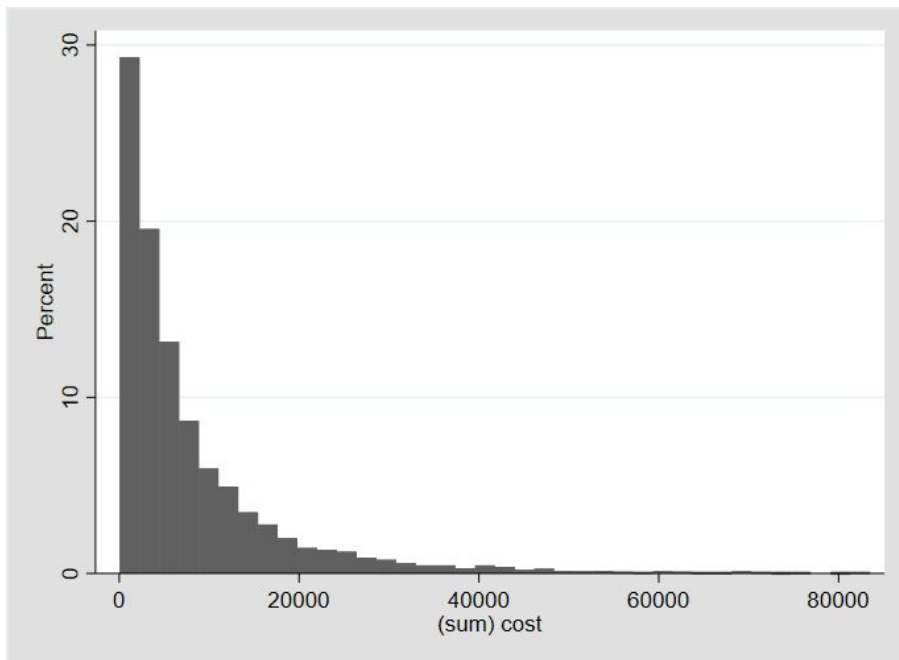


Figure 6: Distribution of cost per spell, across both sites and all times

	Renal recovery				Mortality			
	β	<i>P</i> value	OR	95% CI	β	<i>P</i> value	OR	95% CI
intervention	0.00	.99	1.00	(0.58-1.71)	0.17	.67	1.18	(0.55-2.52)
time	0.01	.39	1.01	(0.99-1.02)	0.00	.63	1.00	(0.98-1.01)
site	0.18	.58	1.20	(0.63-2.28)	0.73	.09	2.08	(0.90-4.79)
site×intervention	0.22	.62	1.24	(0.53-2.92)	0.06	.91	1.07	(0.36-3.15)
time×intervention	-0.01	.61	0.99	(0.96-1.03)	0.00	.89	1.00	(0.96-1.05)
time×site	-0.01	.58	0.99	(0.98-1.01)	0.01	.46	1.01	(0.99-1.03)
time×site×intervention	-0.03	.29	0.97	(0.92-1.03)	-0.03	.44	0.97	(0.91-1.04)

	Progression of AKI stage				Admission to ITU/Renal Unit			
	β	<i>P</i> value	OR	95% CI	β	<i>P</i> value	OR	95% CI
intervention	0.67	.11	1.96	(0.86-4.47)	0.40	.42	1.50	(0.57-4.00)
time	-0.01	.21	0.99	(0.97-1.01)	0.00	.86	1.00	(0.98-1.02)
site	0.52	.29	1.67	(0.64-4.38)	-0.17	.79	0.84	(0.24-2.85)
site×intervention	-0.71	.27	0.49	(0.14-1.71)	-1.18	.18	0.31	(0.05-1.68)
time×intervention	-0.01	.60	0.99	(0.93-1.04)	0.02	.55	1.02	(0.96-1.08)
time×site	0.01	.50	1.01	(0.98-1.04)	-0.01	.63	0.99	(0.96-1.03)
time×site×intervention	0.04	.32	1.04	(0.96-1.13)	0.07	.19	1.08	(0.97-1.20)

	Readmission at 30d				RRT use at 30d			
	β	<i>P</i> value	OR	95% CI	β	<i>P</i> value	OR	95% CI
intervention	0.20	.54	1.22	(0.65-2.29)	-3.32	.03	0.04	(0.00-0.62)
time	0.00	.91	1.00	(0.99-1.01)	0.09	.03	1.09	(1.02-1.20)
site	-0.13	.75	0.88	(0.40-1.91)	19.62	.33	3.33x10 ⁸	(0.04-8.27x10 ³⁰)
site×intervention	-0.16	.77	0.86	(0.31-2.39)	-1.04	.99	0.35	(1.61x10 ⁻⁶⁵ -NA)
time×intervention	-0.03	.23	0.97	(0.93-1.02)	0.00	.98	1.00	(0.83-1.23)
time×site	0.00	.86	1.00	(0.98-1.02)	1.24	.33	3.44	(1.19-96.08)
time×site×intervention	0.01	.84	1.01	(0.94-1.08)	-17.62	.99	2.22x10 ⁻⁸	(NA-4.86x10 ⁵⁶)

	Cardiac arrests			
	β	<i>P</i> value	OR	95% CI
intercept	-6.50			(-6.60 - -6.42)
intervention	-0.60	<.001	0.55	(0.38-0.76)
site	-0.74	<.001	0.48	(0.38-0.59)
site×intervention	0.12	.69	1.13	(0.63-1.99)

Table 2: Results of segmented regression analyses, including all estimated coefficients

The coefficient *intervention* provides an estimate of the difference in outcome between the intervention period and the pre-intervention period at RFH. The two-way interaction *site×intervention* provides an estimate of the difference-in-difference between the two hospital sites. The two-way interaction *time×intervention* provides an estimate of the difference in outcome trend over time in the intervention period compared to the pre-intervention period at RFH. The three-way interaction *time×site×intervention* provides an estimate of the difference-in-difference in the trend between the sites.

	Renal recovery			
	β	<i>P</i> value	OR	95% CI
intervention	-0.10	.73	0.91	(0.52-1.58)
site×intervention	0.32	.47	1.38	(0.58-3.26)
time×intervention	-0.02	.40	0.98	(0.94-1.02)
time×site×intervention	-0.02	.42	0.98	0.92-1.03

Table 3: Results from binary logistic regression (sensitivity analysis)

The coefficient *intervention* provides an estimate of the difference in outcome between the intervention period and the pre-intervention period at RFH. The two-way interaction *site×intervention* provides an estimate of the difference-in-difference between the two hospital sites. The two-way interaction *time×intervention* provides an estimate of the difference in outcome trend over time in the intervention period compared to the pre-intervention period at RFH. The three-way interaction *time×site×intervention* provides an estimate of the difference-in-difference in the trend between the sites.

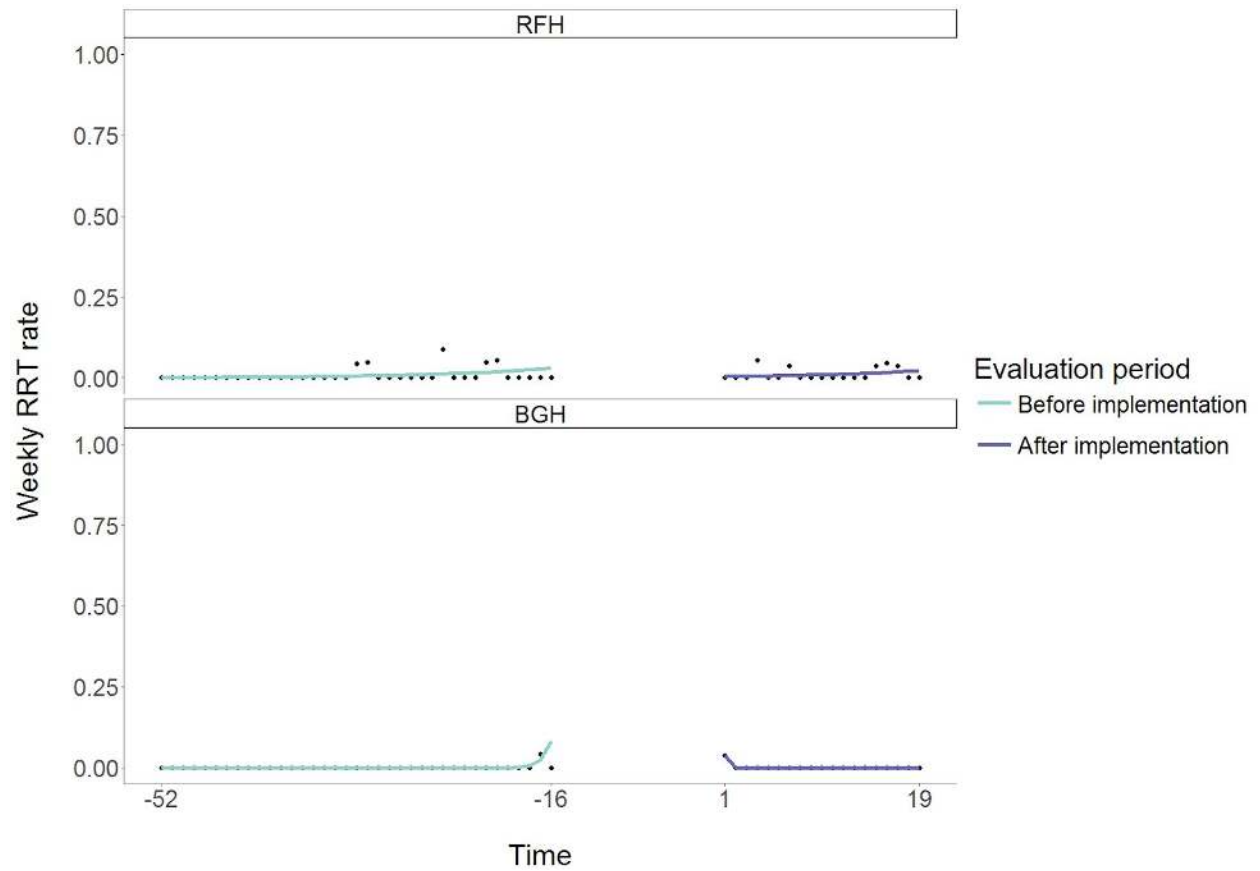


Figure 7: Weekly rates of 30-day dependence on renal replacement therapy at RFH and BGH before and after implementation of the care pathway

RFH = Royal Free Hospital, BGH = Barnet General Hospital.

Individual data points reflect the rate of each outcome for a single week.

Solid lines indicate fitted values from the modelling functions.

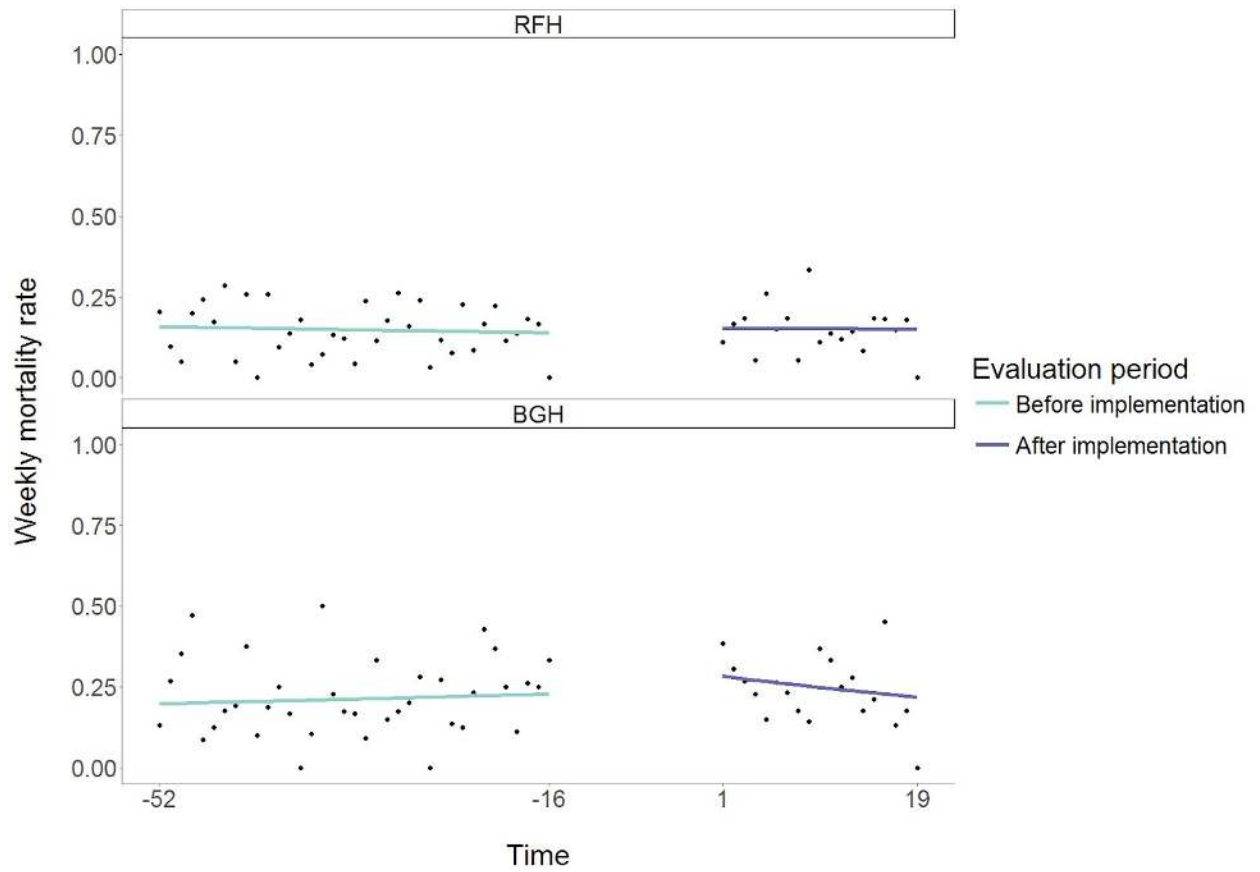


Figure 8: Weekly rates of mortality at RFH and BGH before and after implementation of the care pathway

RFH = Royal Free Hospital, BGH = Barnet General Hospital.

Individual data points reflect the rate of each outcome for a single week.

Solid lines indicate fitted values from the modelling functions.

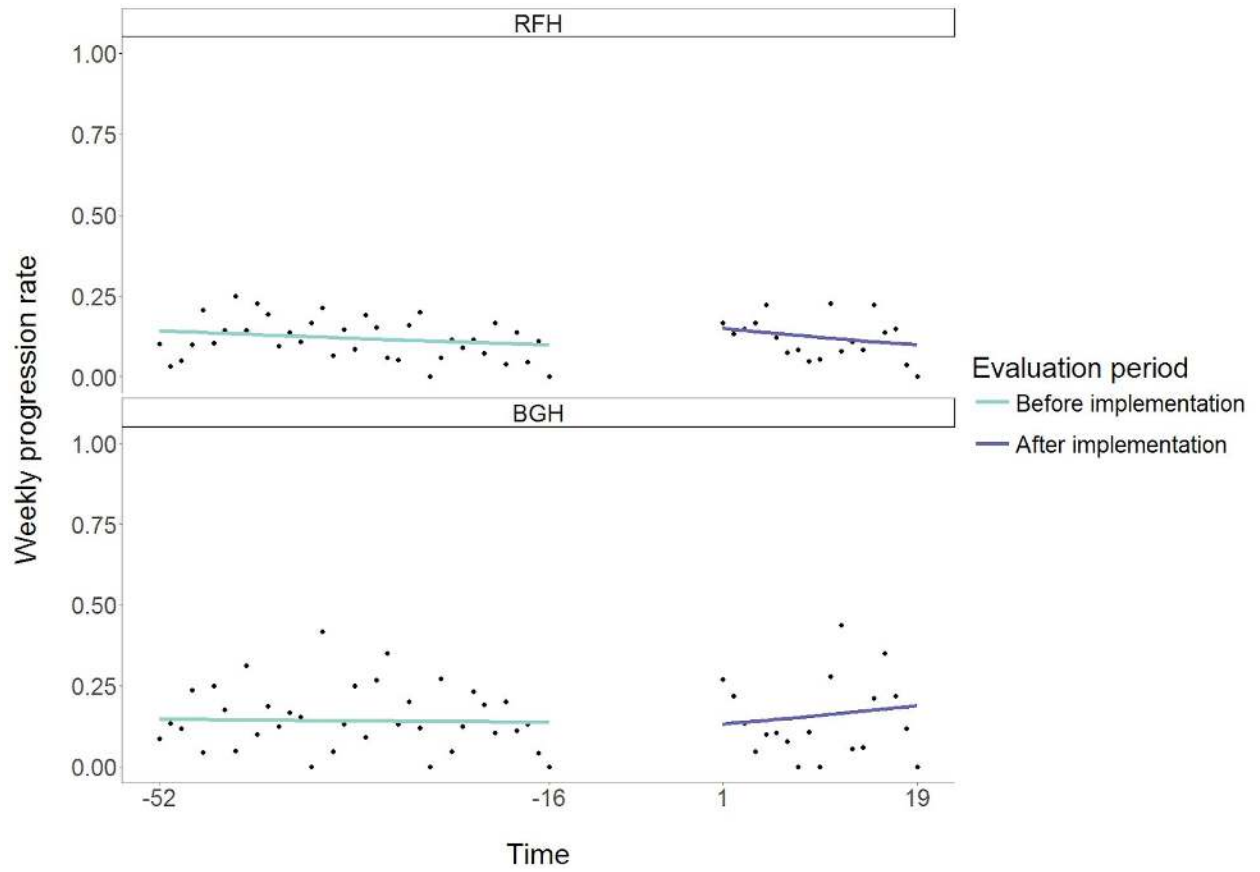


Figure 9: Weekly rates of AKI progression at RFH and BGH before and after implementation of the care pathway

RFH = Royal Free Hospital, BGH = Barnet General Hospital.

Individual data points reflect the rate of each outcome for a single week.

Solid lines indicate fitted values from the modelling functions.

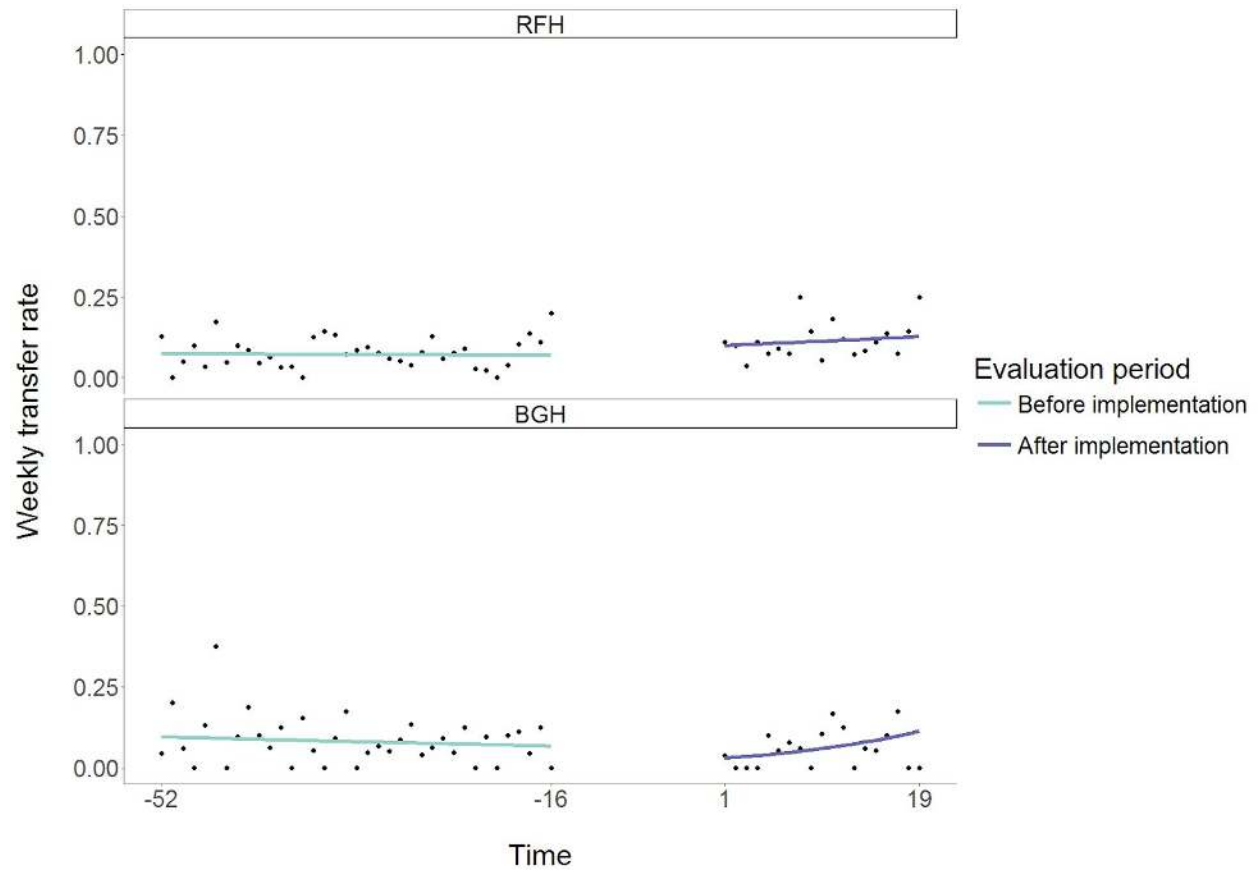


Figure 10: Weekly rates of transfer to ITU/ renal unit at RFH and BGH before and after implementation of the care pathway

RFH = Royal Free Hospital, BGH = Barnet General Hospital.

Individual data points reflect the rate of each outcome for a single week.

Solid lines indicate fitted values from the modelling functions.

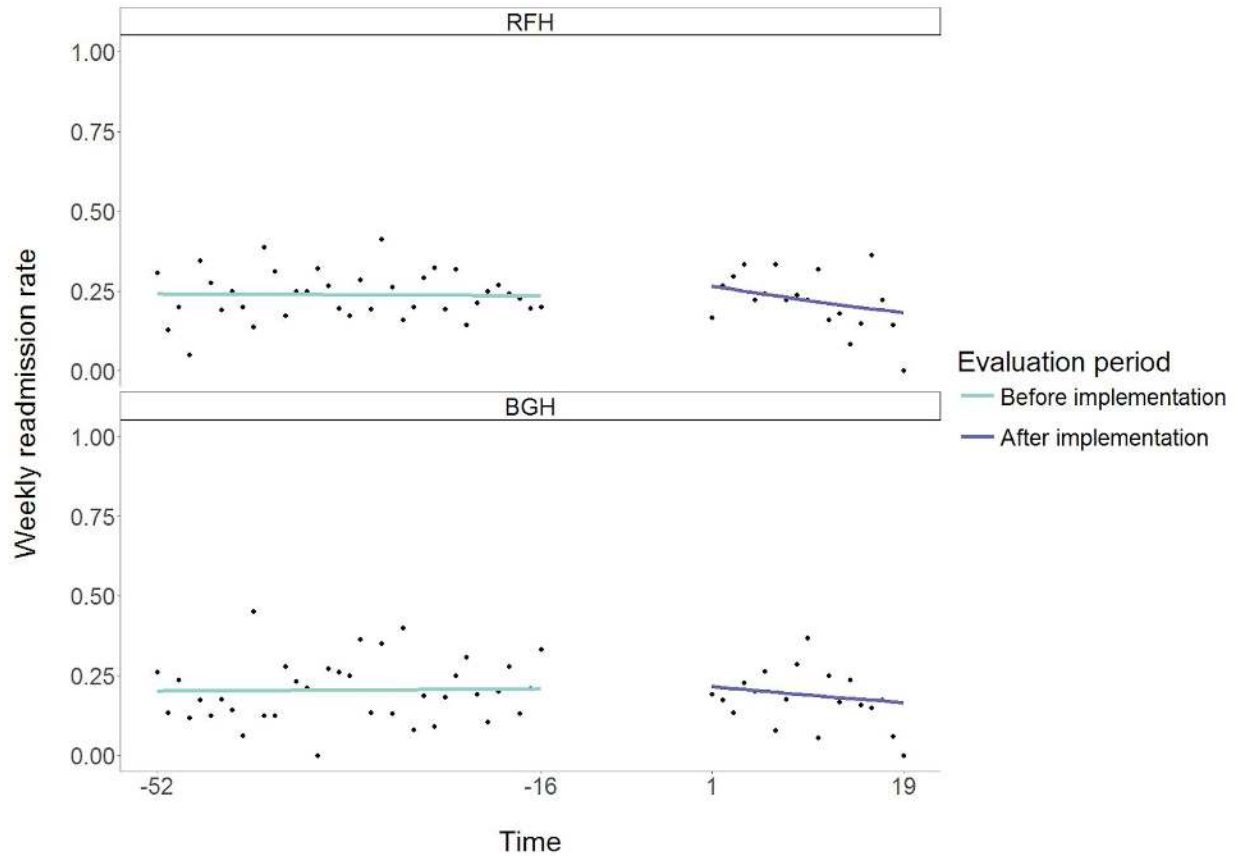


Figure 11: Weekly rates of readmission at RFH and BGH before and after implementation of the care pathway

RFH = Royal Free Hospital, BGH = Barnet General Hospital.

Individual data points reflect the rate of each outcome for a single week.

Solid lines indicate fitted values from the modelling functions.

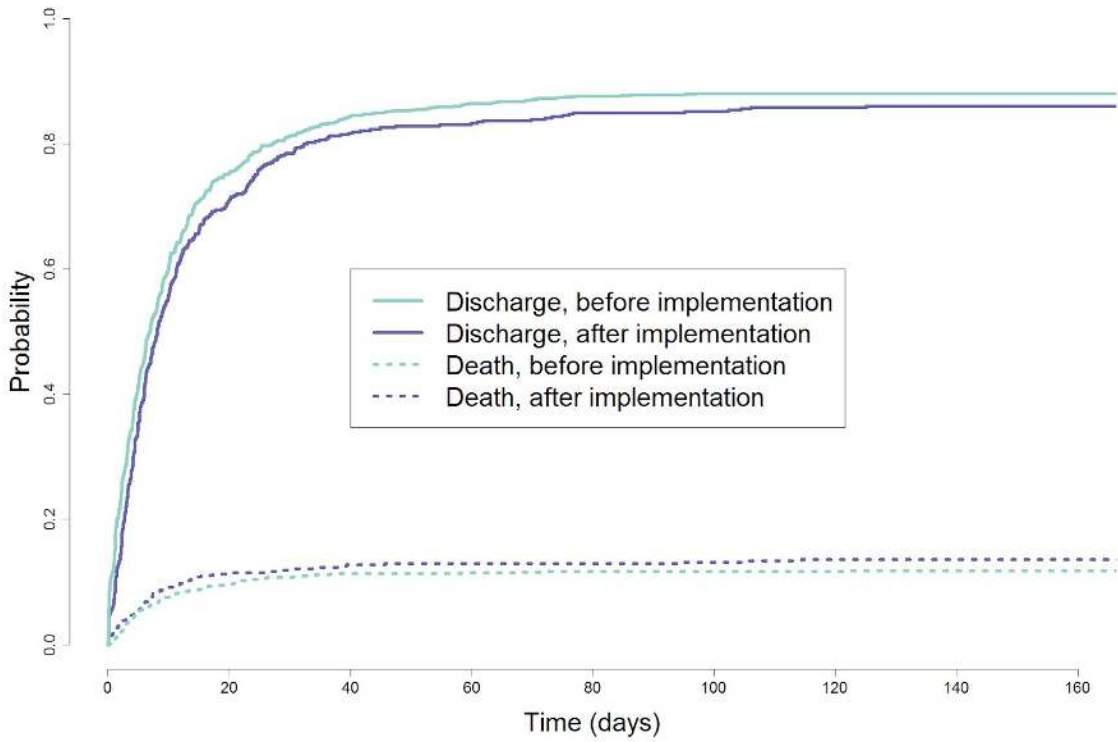


Figure 12: Plot of competing risk analysis for mortality and hospital discharge at RFH

Significant increase in LoS after implementation ($P= .046$). No significant difference in mortality after implementation ($P=.32$)

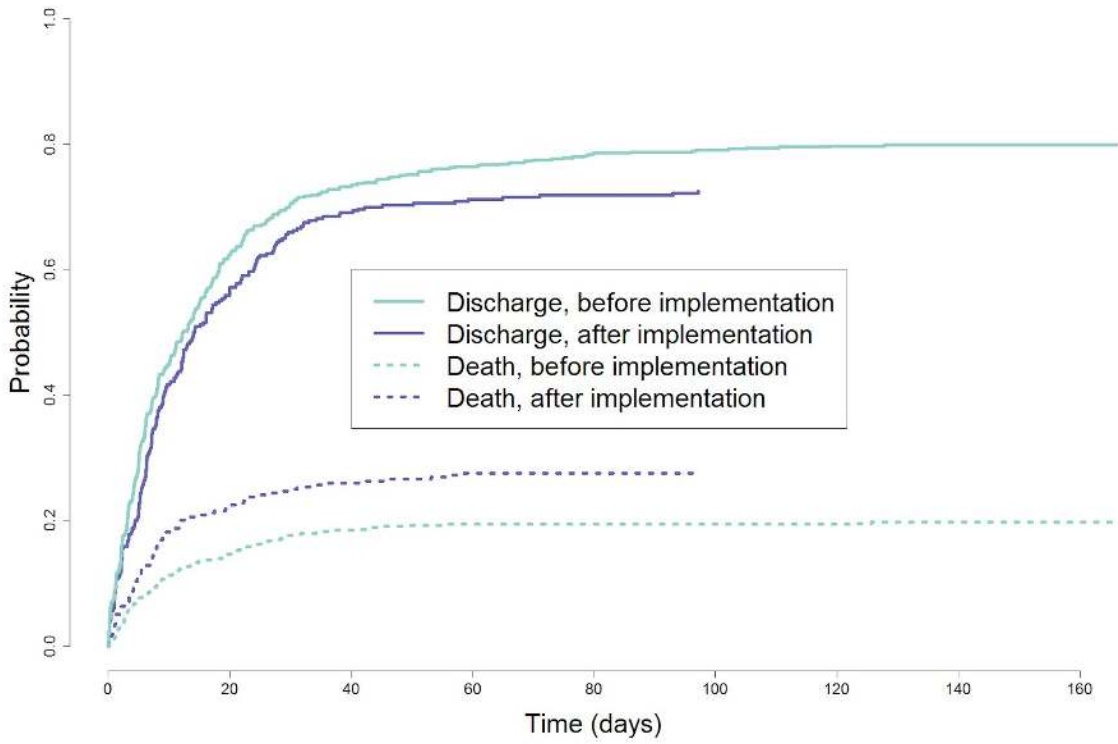


Figure 13: Plot of competing risk analysis for mortality and hospital discharge at BGH

Significant increase in LoS after implementation ($P=.033$). Significant increase in mortality after implementation ($P=.003$). NB: the model estimated odds ratio (OR) for the effects of the intervention on 30-day mortality was not significant (OR=2.08 (95%CI 0.90 - 4.79, $P=.09$).

RFH											
Component	Time period	Pre-intervention			Post-intervention			Difference			
		Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI	P value
Radiology exams	Periods t1&t3 only	£251.75	£228.98	£274.53	£219.32	£197.88	£240.76	-£32.44	-£63.03	-£1.84	.04
	All periods	£241.78	£225.89	£257.66	£215.37	£194.43	£236.30	-£26.41	-£52.10	-£0.72	.04
Pathology exams	Periods t1&t3 only	£534.45	£489.32	£579.58	£441.41	£402.10	£480.71	-£93.04	-£151.76	-£34.32	.002
	All periods	£507.40	£475.87	£538.93	£434.31	£395.92	£472.69	-£73.09	-£121.53	-£24.65	.003
Theatre cutting time	Periods t1&t3 only	£1,209.78	£982.57	£1,436.99	£949.20	£773.18	£1,125.23	-£260.58	-£543.91	£22.75	.07
	All periods	£1,106.97	£957.68	£1,256.26	£978.47	£792.31	£1,164.64	-£128.50	-£363.54	£106.54	.28
Theatre total time	Periods t1&t3 only	£901.27	£762.38	£1,040.16	£781.36	£651.20	£911.53	-£119.90	-£310.60	£70.79	.22
	All periods	£841.46	£745.99	£936.93	£798.94	£661.84	£936.04	-£42.52	-£209.88	£124.83	.62
Length of stay	Periods t1&t3 only	£6,412.47	£5,725.75	£7,099.20	£5,047.79	£4,490.96	£5,604.63	-£1,364.68	-£2,227.27	-£502.10	.002
	All periods	£6,312.34	£5,782.31	£6,842.37	£5,023.42	£4,464.65	£5,582.18	-£1,288.92	-£2,018.84	-£559.01	.001

BGH											
Component	Time period	Pre-intervention			Post-intervention			Difference			
		Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI	P value
Radiology exams	Periods t1&t3 only	£171.15	£154.52	£187.79	£157.83	£141.69	£173.96	-£13.33	-£35.80	£9.15	.25
	All periods	£172.87	£161.22	£184.52	£157.81	£141.77	£173.85	-£15.06	-£34.26	£4.13	.12
Pathology exams	Periods t1&t3 only	£618.41	£541.85	£694.97	£542.90	£483.49	£602.31	-£75.52	-£168.77	£17.74	.11
	All periods	£628.75	£579.91	£677.59	£536.59	£478.41	£594.78	-£92.16	-£164.98	-£19.33	.01
Theatre cutting time	Periods t1&t3 only	£717.52	£470.48	£964.55	£363.76	£239.74	£487.78	-£353.75	-£615.93	-£91.57	.008

	All periods	£570.91	£427.01	£714.81	£356.34	£229.38	£483.29	-£214.57	-£401.39	-£27.76	.02
Theatre total time	Periods t1&t3 only	£455.45	£330.19	£580.72	£292.41	£206.12	£378.71	-£163.04	-£312.04	-£14.04	.03
	All periods	£383.51	£305.42	£461.60	£292.34	£202.01	£382.66	-£91.18	-£211.39	£29.04	.14
Length of stay	Periods t1&t3 only	£5,469.91	£4,619.59	£6,320.22	£4,559.53	£3,991.79	£5,127.27	-£910.38	-£1,872.28	£51.53	.06
	All periods	£5,644.89	£5,099.14	£6,190.64	£4,511.97	£3,965.38	£5,058.56	-£1,132.92	-£1,866.18	-£399.66	.002

Difference-in-difference					
Component	Time period	Mean	Lower CI	Upper CI	P value
Radiology exams	Periods t1&t3 only	-£19.11	-£56.35	£18.12	.31
	All periods	-£11.35	-£42.97	£20.27	.48
Pathology exams	Periods t1&t3 only	-£17.53	-£127.13	£92.08	.75
	All periods	£19.07	-£67.80	£105.94	.67
Theatre cutting time	Periods t1&t3 only	£93.18	-£289.96	£476.31	.63
	All periods	£86.08	-£217.09	£389.25	.58
Theatre total time	Periods t1&t3 only	£43.13	-£196.92	£283.19	.72
	All periods	£48.65	-£158.95	£256.25	.65
Length of stay	Periods t1&t3 only	-£454.31	-£1,736.82	£828.21	.49
	All periods	-£156.00	-£1,170.46	£858.45	.76

Table 4: Cost components analyses

RFH = Royal Free Hospital, BGH = Barnet General Hospital. CI = Confidence Interval. t1 = May to September 2016; t2 = May to September 2017.