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A prospective cohort study characterising patients declined emergency laparotomy: survival in the 'NoLap' population*

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Summary

Patients eligible for emergency laparotomy who do not proceed to surgery are not as well-characterised as patients who do proceed to surgery. We studied patients eligible for laparotomy, as defined by the National Emergency Laparotomy Audit criteria, from August 2015 to October 2016. We analysed the association of individual variables with survival and two composite scores: P-POSSUM and a general survival model. Out of 314 patients, 214 (68%) underwent laparotomy and 100 (32%) did not. Median (IQR [range]) follow-up was 1.3 (0.1–1.8 [0.0–2.5]) years for the cohort, 1.5 (1.1–2.0 [0.0–2.6]) years after laparotomy and 0.0 (0.0–1.1 [0.0–2.2]) years without laparotomy. There were 126/314 (40%) deaths in the follow-up period, 52/214 (24%) deaths after laparotomy and 74/100 (74%) deaths without surgery. Ninety out of 126 deaths (71%) were within 1 month of hospital admission. Patient variables were different for the two groups, which when combined in the general survival model generated background median (IQR [range]) life expectancies of 12 (6–21 [0–49]) and 4 (2–6 [0–36]) years, respectively, $p < 0.0001$. 'Poor fitness' precluded laparotomy in 74/100 (74%) patients. The decision to not operate involved a consultant less often than the decision to operate: 66/100 (66%) vs. 178/214 (83%), $p = 0.001$. Our study supports the contention that survival beyond 30 postoperative days could be predicted reasonably accurately. Survival in patients who did not have laparotomy was shorter than expected. Emergency laparotomy might have prolonged survival in some patients.

Introduction

Emergency laparotomy is indicated for a range of acute surgical pathologies, the purpose of which is to prolong the duration and maintain the quality of a patient's life [1, 2]. Until recently, this patient population remained undefined, but the introduction of the National Emergency Laparotomy Audit (NELA) in the UK has documented nearly 30,000 cases a year in England and Wales. Patients are predominately older adults with risk-adjusted rates of death in the first postoperative month of 5%-17% [3-6], consistent with similar populations in other countries [7-10].

Characterisation of the emergency laparotomy population has led NELA to publish criteria that define a standard pathway of care to improve outcomes for these patients. This has resulted in improved awareness and integration of targeted standardised process pathways which have been accompanied by a reduction in postoperative mortality, from 12% to 10% [6-8]. However, there remains an undefined surgical population not studied by the current NELA database that could provide more insight in to emergency laparotomy care: patients who fulfil the criteria for emergency laparotomy but who do not proceed to surgery ('NoLap') [9, 10]. The only information in relation to these patients comes from the recently published Perth (Australia) Emergency Laparotomy Audit that reported 13/211 (6%) of patients eligible for laparotomy did not proceed to surgery [11].

We aimed to characterise a consecutive series of patients eligible for emergency laparotomy who did not proceed to surgery, compared with patients who did. We aimed to compare patient variables and process factors associated with survival in both groups to gain insight into this uncharacterised population.

Methods

We reported this study using the STROBE Guidelines [12]. From August 2015 to October 2016, we prospectively studied adults (18 years or older) admitted to one district general hospital, for whom emergency laparotomy was indicated. We did not seek ethical approval for the study, which was approved by the Clinical Effectiveness Department of NHS Greater Glasgow and Clyde. The Caldicott guardian and the NHS Greater Glasgow and Clyde Research and Development approved use of the NELA database.

The surgical department consisted of ten consultants (breast, upper gastrointestinal, colorectal; minimum of two years' on-call experience), serving a population of around 200,000 from both rural and urban areas. The on-call team consisted of one consultant, one surgical trainee (post-MRCS up to ST7) and two foundation year doctors. On average each week there were 100 inpatient admissions and 4-5 emergency laparotomies.

We did not study patients excluded by NELA criteria, for instance conditions related to the appendix or gallbladder, herniae with no bowel resection, trauma and planned return to theatre [13]. Patients who had undergone elective surgery were eligible for inclusion, if emergency laparotomy was indicated for postoperative complications. However, patients were excluded if the indication for emergency laparotomy followed a different intervention, for instance radiological drainage of an abscess.

The 'NoLap' group was patients who fulfilled the NELA criteria but who did not proceed to surgery. The surgical department was made aware of the audit to ensure that we included patients from non-surgical wards. However, we did not guide decision-making. The on-call surgical registrar recorded patient details on a secure database in a locked room in the surgical department. To reinforce identification, theatre logbooks and emergency CT scan lists were reviewed. We recorded the reasons for decisions not to proceed to surgery, which we categorised as: patient decision; or surgery likely to be futile, either due to poor patient fitness or advanced malignancy.

We recorded patient: age; sex; ASA physical status [14, 15]; baseline blood tests including creatinine, estimated glomerular filtration rate (eGFR), haemoglobin and albumin, immediate pre-operative serum lactate and creatinine (measured within four hours of the surgical review); predicted pre-operative P-POSSuM [16]; and the surgical diagnosis. The Cockcroft-Gault equation was used to calculate estimated glomerular filtration rate (eGFR). We also recorded co-morbidity: acute coronary syndrome; stroke; heart failure; peripheral arterial disease; and a history of angina or transient ischaemic (cerebral) attack. Baseline functional status of the patient was recorded; fully independent or not. We recorded delivery of NELA standards for all patients in whom emergency laparotomy was indicated. We calculated survival curves with a general survival model [17-19], with mortality hazard recently been shown to temporarily increase 25-fold by the acute surgical abdomen [20]. Censor date was 30th November 2017 or date of death, whichever came first.

We compared continuous data with ‘t’ test and Kruskal-Wallis test, as appropriate, and rates with Fisher exact test. The Kaplan-Meier estimate was used for survival and model fit was calculated with the Likelihood ratio test, Wald test and Log rank test. Variables associated with mortality at a threshold of $p < 0.1$ were included in the multivariable analysis with stepwise backward elimination. The calibration of P-POSSuM and general models with mortality at 30 days was assessed with calibration belts [21]. Results were analysed with multiple imputation which was used for missing data. We used R [22] and SPSS (version 24, Armock, NY: IBM Corp) for statistical analyses.

Results

We studied 314 patients in whom emergency laparotomy was indicated (Fig. 1): 100 did not proceed to surgery whilst 214 had emergency laparotomy. Patients who did not undergo laparotomy were: older; more dependent; more likely to have co-morbidity, with higher ASA physical status; and were more likely to present with bowel ischaemia (Table 1 and Fig. 2). The median life expectancy of those not operated on was one third the life expectancy of patients who had surgery, although for some patients in both groups life expectancy exceeded three decades.

Of the 100 patients who did not have surgery, 80 (80%) were reviewed on general surgical wards, 17 (17%) on medical wards and 3 (3%) elsewhere. NELA key standards of care were delivered less often when not followed by laparotomy, except for the speed at which the decision not to operate was reached (Table 2). Reasons for not operating were: 80 (80%) considered futile, due to poor fitness in 74 patients or advanced malignancy in six patients; whilst four (4%) patients declined surgery. No reason was documented for the remaining 16 (16%) patients.

Median (IQR [range]) follow-up was 1.3 (0.1-1.8 [0.0-2.5]) years for the cohort, 1.5 (1.1-2.0 [0.0-2.6]) years after laparotomy and 0.0 (0.0-1.1 [0.0-2.2]) years for patients who did not have surgery. Overall there were 126/314 (40%) deaths during the study period, 52/214 (24%) deaths after laparotomy and 74/100 (74%) deaths without surgery. Most of the 126 deaths occurred within one month of acute hospital admission: 90/126 (71%) cohort deaths; 27/52 (52%) deaths after laparotomy; and 63/74 (85%) deaths without surgery.

The observed mortality rate in the month after laparotomy – 27/214 (13%) – was not statistically different to the rates predicted by the P-POSSuM model and general model, 37/214 (17%) and 26/214 (12%), respectively, $p = 0.22$ and $p = 1$. The mortality rate in one month of 63/100 (63%) in the 'NoLap' group was more than expected had these 100 patients had laparotomy: P-POSSuM predicted 40/100 (40%) deaths; and the general model predicted 30/100 (30%) deaths, $p = 0.002$ and $p < 0.001$, respectively. The survival curve predicted by the general model matched the observed survival after laparotomy, except for mortality between one month and one year, a period that is not modelled (Fig. 3a). Survival without surgery was worse than that modelled had the 100 patients had laparotomy (Fig. 3b). Calibration belt analyses suggest that both models underestimated deaths in the first month for patients with low expected mortality rates and overestimated deaths in patients with high expected mortality rates (see also Supplementary Information Figs. S1a-f).

Several variables were associated with survival after laparotomy, which was reduced to two variables by multivariate analysis: background mortality (general model); and acute pre-operative lactate concentration (Table 3). These same variables were also associated with survival in patients who did not have surgery, with similar hazard ratios, for whom the multivariate model was age, sex and P-POSSuM mortality (Table 4).

Discussion

We found that patients who did not proceed to surgery in whom emergency laparotomy was indicated had higher expected mortality and observed mortality than patients who did have laparotomy.

This is the first study to characterise a consecutive series of 'NoLap' UK patients, which unexpectedly constituted a third of admissions with acute surgical abdomen. In turn, a third of these patients were alive 30 days after admission.

The decision to operate or not is complex. It is guided by objective patient characteristics and the subjective experiences of the emergency surgeon and peri-operative team. The most common documented reasons for not operating were 'poor fitness' and 'not fit enough for surgery'. In most cases the diagnosis of fitness too poor to proceed to laparotomy was not explicitly justified in the notes, although the average survival predicted by a combination of objective characteristics was worse than the survival predicted for patients who did proceed to laparotomy. For example, patients who did not undergo laparotomy were older, with worse baseline renal function and albumin levels and with worse acute physiological derangement, in particular raised lactate concentration. All of these factors are associated with higher mortality and shorter median survival [14, 15, 23].

The mortalities predicted by the P-Possum model and the general model were similar to the survival observed for patients who had emergency laparotomy. However, observed survival shorter than expected in 'NoLap' patients suggests that more might have survived had they proceeded to surgery. Whilst this is an important finding, our results are far from directive or conclusive. We hope to provoke further large-scale work to address the reasons for this disparity. In addition to a missed opportunity, the disparity between observed and predicted survival could be due to unmeasured confounding factors, in both chronic health and acute illness [24], and patients preferring symptom palliation to the possible prolongation of death afforded by surgery and subsequent critical care. We acknowledge that NELA proposes that P-POSSuM is a guide to identify high-risk patients and drive early consultant input, rather than influence laparotomy decision-making [3, 25, 26, 27].

Decisions not to operate were taken on average made more quickly than decisions to operate and were less often informed by CT scan, formal risk assessment, consultant surgical documentation or admission to critical care. It is unclear whether rapid decisions not to operate were an efficient response to prognosis and patient wishes or in error. One might reasonably expect that decisions not to operate would be unaffected by these factors for patients who presented in extremis and had otherwise short life expectancies and poor quality of life, for instance due to severe heart or lung disease or end-stage metastatic disease. We think that consultant input in our unit is possibly better than many other hospitals, as consultant surgeons attend > 95% of emergency laparotomies, which compares favourably the average of 84% reported by NELA [6].

We think that our patient pathway might be improved by establishing criteria that prompt consultant surgical review and CT scan, which could be a combination of chronic health and acute physiological derangement, perhaps as summarised by P-PoSSUM or general survival models. This approach might improve the understanding of pathology, facilitating more informed discussions with the patient and their family, even though it may not change interventions or outcomes. However, improved information could lead to changes in conservative management, whereby the same patient with a decision not to proceed to laparotomy is admitted to a High Dependency Unit to optimise their outcome rather than a general surgical ward. In addition, key areas could be targeted for future novel surgical approaches and technologies, for instance the diagnosis of gastrointestinal ischaemia often preceded the decision not to operate. The non-operative pathway should also consider involving palliative care specialists at an early stage [28].

One strength of our study is that it was prospective and the research team included patients from non-general surgical wards, including medical wards, critical care and gynaecology, which do not usually contribute to audits of surgical deaths. We acknowledge some important limitations. Our findings are unlikely to be applicable to all hospitals as it was a single centre study of a small number of patients compared with national audits. Although the study included ten different emergency surgeons of differing sub-specialties, it may have selection bias due to local surgical practice. Despite the data being prospectively collected we accept that we might have missed some patients, for instance when a decision not to operate was made by a specialty other than the on-call general surgeon. Also, the diagnosis of a pathology manageable by laparotomy could have been incorrect, whether or not it was supported by a CT scan. Finally, some patient data were missing.

In conclusion, this is the first UK study to characterise the third of patients who are eligible for emergency laparotomy but who do not proceed to surgery, of whom one third survive at least 30 days. Predicted survival suggested that some patients who did not proceed to surgery might have benefitted from laparotomy, whilst some patients who had laparotomy might have benefitted from non-surgical interventions. Decisions to operate or not are complex. We hope that further research will improve the management of patients with acute abdomen and may inform how to best match patients to operative management or symptomatic management without surgery.

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References

1. Akinbami F, Askari R, Steinberg J, Panizales M, Rogers S. Factors affecting morbidity in emergency general surgery. *The American Journal of Surgery* 2011; **201:** 456-62.
2. Leung E, Ferjani AM, Stellard N, Wong LS. Predicting post-operative mortality in patients undergoing colorectal surgery using P-POSSUM and CR-POSSUM scores: a prospective study. *International Journal of Colorectal Disease* 2009; **24:** 1459-64.
3. National Emergency Laparotomy Audit. Second patient report of the National Emergency Laparotomy Audit. *Royal College of Anaesthetists* London 2016.
4. National Emergency Laparotomy Audit. First patient report of the National Emergency Laparotomy Audit. *Royal College of Anaesthetists* London 2015.
5. National Emergency Laparotomy Audit. The Third Patient Report of the National Emergency Laparotomy Audit - Full Patient Report. *Royal College of Anaesthetists* London 2017.
6. National Emergency Laparotomy Audit. The Fourth Patient Report of the National Emergency Laparotomy Audit (NELA) December 2016-November 2017: Executive Summary. *Royal College of Anaesthetists* London 2018.
7. Huddart S, Peden C, Swart M, et al. Use of a pathway quality improvement care bundle to reduce mortality after emergency laparotomy (ELPQuiC) Collaborator Group. *British Journal of Surgery* 2015; **102:** 57-66.
8. Tengberg L, Bay-Nielson M, Bisgaard T, Cihoric M, Lauritsen M, Foss N. Multidisciplinary perioperative protocol in patients undergoing acute high-risk abdominal surgery. *British Journal of Surgery* 2017; **104:** 463-71.
9. Szatmany P, Arora S, Sevdalis N. To operate or not to operate? A multi-method analysis of decision making in surgery. *The American Journal of Surgery* 2010; **200:** 298-304.
10. Ko CY, Hall BL, Hart AJ, Cohen ME, Hoyt DB. The American College of Surgeons National Surgical Quality Improvement Program: Achieving Better and Safer Surgery. *The Joint Commission Journal on Quality and Patient Safety* 2015; **41**: 199-204.
11. Broughton KJ, Aldridge O, Pradhan S, Aitken JR. The Perth Emergency Laparotomy Audit *ANZ Journal of Surgery* 2017; **87.**
12. von Elm E, Altman D, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies. *Annals of Internal Medicine* 2007; **147:** 573-7.

13. National Emergency Laparotomy Audit. Audit Inclusion and Exclusion Criteria v 1.5: NELA Inclusion Criteria 2015.
14. American Society of Anaesthesiologists. ASA Physical Classification System; 2014.
15. Abbas S, Kahokher A, Mahmoud M, Hill. A Physiologic modification of the American Society of Anaesthesiology Score (ASA) for Prediction of Morbidity and Mortality after Emergency Laparotomy. *The Internet Journal of Surgery* 2010; **20**: 2.
16. Prytherch D, Whiteley M, Higgins B, Weaver P, Prout W, Powell S. POSSUM and Portsmouth POSSUM for predicting mortality. Physiological and operative severity score for the enumeration of Mortality and Morbidity. *British Journal of Surgery* 1998; **85:** 1217-20.
17. Carlisle JB, Danjoux G, Kerr K, Snowden C, Swart M. Validation of long-term survival prediction for scheduled abdominal aortic aneurysm repair with an independent calculator using only pre-operative variables. *Anaesthesia* 2015; **70**: 654-65.
18. Carlisle J. Commentary: 'Life is a line, not a dot'. *Colorectal Disease* 2017; **19**: 64-6.
19. Carlisle JB. General survival model. 2013. https://www.dropbox.com/sh/b9liswknzyzd3f2/AAA8ljZZhcbvldLSlJBTmmIba?dl=&preview=Risk+calculator+version+%27naked%27+2019+June.xlsx %3B= %3B0= (accessed 13th July 2019).
20. Carlisle JB. Risk prediction models for major surgery: composing a new tune. *Anaesthesia* 2019; **74** (Suppl. 1): 7-12.
21. Nattino G, Finazzi S, Bertolini G. A new calibration test and a reappraisal of the calibration belt for the assessment of prediction models based on dichotomous outcomes. *Statistics in Medicine* 2014; **33**: 2390-407.
22. R Core Team: R: *A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. 2013. http://www.R-project.org. (accessed 13/07/2019).
23. Lin H-S, Watts J, Peel N, Hubbard R. Frailty and post-operative outcomes in older surgical patients: a systematic review *BMC Geriatrics* 2016; **16:** 157.
24. Parmar KL, Law J, Carter B et al. Frailty in Older Patients Undergoing Emergency Laparotomy:Results from the UK Observational Emergency Laparotomy and Frailty (ELF) Study. *Annals of Surgery* 2019; doi: 10.1097/SLA.0000000000003402. [Epub ahead of print]
25. Bann S, Sarin S. Comparative audit: the trouble with POSSUM. *Journal of the Royal Society of Medicine* 2001; **94:** 632-4.

26. NCEPOD. Knowing the risk; a review of the Peri-operative Care of Surgical Patients. 2011.
27. Royal College of Surgeons. Emergency Surgery, Standards for Unscheduled Surgical Care, Guidance for Providers, Commissioners and Service Planners. London; 2011.
28. Cauley CE, Panizales MT, Reznor G, et al. Outcomes after emergency abdominal surgery in patients with advanced cancer: Opportunities to reduce complications and improve palliative care. *Journal of Trauma and Acute Care Surgery* 2015; **79:** 399-406.

Table 1 Characteristics of 314 patients in whom emergency laparotomy was indicated, categorised by whether the patient proceeded to surgery (n = 214) or not (n = 100). Values are mean (SD), median (IQR [range]) or number (proportion).

Characteristic	Total (n = 314)	Emergency laparotomy		p value
		No (n = 100)	Yes (n = 214)	
Age; years	68.3 (15.5)	78.0 (11.1)	63.7 (15.2)	< 0.001
Height; cm	165.7 (10.2)	162.1 (9.7)	167.2 (10.0)	< 0.001
Weight: kg	70.6 (19.4)	64.6 (16.9)	73.1 (19.9)	< 0.001
Sex; male	149 (48%)	45 (45%)	104 (49%)	0.552
ASA; 1 or 2	92 (30%)	5 (5%)	87 (41%)	< 0.001
Past history*	313	100	213	
Acute coronary syndrome	50 (16%)	17 (17%)	33 (16%)	
Stroke	25 (8%)	13 (13%)	12 (6%)	
Heart failure	25 (8%)	15 (15%)	10 (5%)	< 0.001
Peripheral arterial disease	15 (5%)	8 (8%)	7 (3%)	
Angina	28 (9%)	13 (13%)	15 (7%)	
TIA	9 (3%)	2 (2%)	7 (3%)	
Functional status; independent†	200 (65%)	29 (30%)	171 (81%)	< 0.001
Baseline blood results				
Creatinine‡; $\mu mol.l^{-1}$	71 (63-86 [43-452])	74 (64-99 [43-452])	70 (63-81 [46-162])	< 0.001
eGFR§; $ml.min^{-1}.1.73m^{-2}$	72 (53-99 [353])	56 (39-72 [162])	82 (60-106 [337])	< 0.001
Haemoglobin; $g.l^{-1}$	127 (112-142 [55-201])	126 (110-139 [66-177])	128 (113-145 [55-201])	0.018
Albumin§; $g.l^{-1}$	35 (31-38 [19-47])	32 (29-36 [20-44])	36 (33-39 [19-47])	< 0.001
Pre-operative blood results				
Creatinine*; $\mu mol.l^{-1}$	77 (63-119 [37-614])	108 (73-173 [43-614])	72 (61-99 [37-426])	< 0.001
eGFR; $ml.min^{-1}.1.73m^{-2}$	71 (45-103 [205])	43 (28-68 [164])	82 (58-109 [199])	< 0.001
Haemoglobin; $g.l^{-1}$	127 (112-142 [146])	126 (110-139 [111])	128 (113-145 [146])	0.13
Lactate**; $mg.dl^{-1}$	2.2 (1.2-4.0 [0.0-19.4])	3.3 (1.5-5.5 [0.1-19.4])	1.8 (1.0-3.5 [0.0-11.3])	< 0.001
Indication for surgery†	310	98	212	
Ischaemia	35 (11%)	23 (24%)	12 (6%)	
Intestinal obstruction	121 (39%)	24 (25%)	97 (46%)	<0.001
Intestinal perforation	52 (17%)	21 (21%)	31 (15%)	

Peritonitis	6 (2%)	1 (1%)	5 (2%)	
Intra-abdominal abscess	18 (6%)	7 (7%)	11 (5%)	
Colitis	6 (2%)	0	6 (3%)	
Bleeding	7 (2%)	3 (3%)	4 (2%)	
Fistula	3 (1%)	0	3 (1%)	
Anastomotic leak	3 (1%)	0	3 (1%)	
Multiple diagnoses	39 (13%)	7 (7%)	32 (15%)	
Other	20 (6%)	12 (12%)	8 (4%)	
Predicted monthly mortality: %				
Background	0.4 (0.1-1.1 [0.0-9.8])	1.2 (0.7-2.1 [0.0-9.8])	0.2 (0.1-0.6 [0.0-5.0])	< 0.001
Postoperative				
P-POSSuM	13 (4-35 [1-99])††	29 (14-74 [1-99])	6 (3-20 [1-98])††	< 0.001
General model	10 (3-25 [0-100])‡‡	29 (15-44 [0-96])‡‡	6 (2-15 [0-100])	< 0.001
Predicted median life expectancy: y				
Background	8 (4-17 [0-49])	4 (2-6 [0-36])	12 (6-21 [0-49])	< 0.001
'Postoperative'	8 (2-16 [0-49])	2 (0-5 [0-36])	12 (5-21 [0-49])	< 0.001

Missing values: *1, †4, ‡32, §73, **77, ††2, ‡‡10

‡‡Value exceeded 100% for eight patients.

TIA, transient (cerebral) ischaemic attack; eGFR, estimated glomerular filtration rate.

Table 2 The national emergency laparotomy audit (NELA) pre-operative standards of care delivered to 314 patients admitted with acute surgical abdomen, categorised by whether they did not or did proceed to laparotomy. Values are number (proportion) or median (IQR [range]).

NELA standard of care	Total (n = 314)	Emergency laparotomy No (n = 100)	Emergency laparotomy Yes (n = 214)	p value
Computerised tomography				
Before decision	243 (77%)	67 (67%)	176 (82%)	0.003
Reported by consultant*	180 (74%)	52 (78%)	128 (73%)	0.003
Patient was risk assessed	35 (11%)	4 (4%)	31 (15%)	< 0.001
Mortality risk was documented	103 (33%)	24 (24%)	79 (37%)	< 0.001
Consultant decision documented	244 (78%)	66 (66%)	178 (83%)	0.001
Admission to surgeon review time †				
Documented	193 (62%)	68 (68%)	125 (58%)	0.001
Value; h	11 (4-19 [0-755])	4 (1-14 [0-662])	13 (7-19 [0-755])	< 0.001
Time from surgeon review to decision ‡				
Documented	166 (53%)	67 (67%)	99 (46%)	0.001
Value; h	5 (0-23 [0-840])	2 (0-13 [0-115])	8 (0-31 [0-840])	0.023
P-POSSuM mortality ≥ 5%¶	212 (68%)	89 (89%)	123 (58%)	< 0.001
Admitted to critical care	136 (64%)	15 (17%)	121 (98%)	< 0.001

Number of patients for whom values were missing: *83; †121 ‡151; ¶2;
NELA, national emergency laparotomy audit.

Table 3 Univariate and multivariate association of variables with survival for 214 patients with acute surgical abdomens who proceeded to laparotomy.

	Univariate			Multivariate*		
	HR (95% CI)	**z**	**p value**	**HR (95% CI)**	**z**	**p value**
Sex; male	0.94 (0.55-1.63)	-0.2	0.83			
Height; cm	0.99 (0.96-1.02)	-0.8	0.40			
Weight; kg	0.98 (0.97-1.00)	-1.9	0.062			
Age; years	1.03 (1.01-1.05)	2.9	0.0037			
Heart failure	3.3 (1.4-7.8)	2.8	0.0056			
Functional status;						
Independent	1.23 (1.04-1.47)	2.4	0.018			
Blood results						
Baseline						
Creatinine; $\mu mol.l^{-1}$	1.01 (1.00-1.03)	2.3	0.023			
eGFR; $ml.min^{-1}.1.73m^{-2}$	0.98 (0.97-1.00)	-2.7	0.0071			
Haemoglobin; $g.l^{-1}$	0.98 (0.97-1.00)	-2.4	0.015			
Albumin; $g.l^{-1}$	0.96 (0.91-1.01)	-1.7	0.09			
Pre-operative						
Creatinine; $\mu mol.l^{-1}$	1.00 (1.00-1.01)	2.0	0.042			
eGFR; $ml.min^{-1}.1.73m^{-2}$						
Haemoglobin; $g.l^{-1}$	0.99 (0.98-1.00)	-1.57	0.12			
Lactate; $mg.dl^{-1}$	1.15 (1.00-1.31)	2.0	0.044	1.11 (0.97-1.28)	1.51	0.13
Predicted monthly mortality; %						
Pre-operative						
General model	1.63 (1.37-1.95)	5.4	< 0.001	2.16 (1.62-2.87)	5.28	< 0.001
Postoperative						
P-POSSuM	1.02 (1.01-1.03)	4.0	< 0.001			
General model	1.02 (1.01-1.03)	5.0	< 0.001			
Predicted median life expectancy; y						
Background	0.94 (0.90-0.97)	-3.6	< 0.001			
Postoperative	0.94 (0.91-0.98)	-3.3	< 0.001			

HR, hazard ratio; z, z value, eGFR, estimated glomerular filtration rate.
*Likelihood ratio test 21.1, p = 0.00003; Wald test 32.9, p = 0.00000007; Log-rank test 42.4, p = 0.0000000006.

Table 4 Univariate and multivariate association of variables with survival for 100 patients admitted with acute surgical abdomens who did not proceed to laparotomy.

	Univariate			Multivariate*		
	HR (95% CI)	**z**	**p value**	**HR (95% CI)**	**z**	**p value**
Sex; male	0.96 (0.61-1.52)	-0.2	0.86	0.93 (0.57-1.51)	-0.3	0.76
Height; cm	0.99 (0.97-1.02)	-0.4	0.67			
Weight; kg	0.97 (0.95-0.98)	-3.7	0.00021			
Age; years	1.04 (1.02-1.07)	3.3	0.00083	1.04 (1.02-1.07)	3.3	0.00083
Heart failure	0.79 (0.40-1.54)	-0.7	0.49			
Functional status;						
Independent	1.12 (1.01-1.23)	2.3	0.024			
Blood results						
Baseline						
Creatinine; μmol.l^{-1}	1.00 (1.00-1.05)	1.0	0.31			
eGFR; ml.min^{-1}.1.73m^{-2}	0.99 (0.98-1.00)	-2.7	0.0060			
Haemoglobin; g.l^{-1}	1.00 (0.98-1.01)	-0.5	0.64			
Albumin; g.l^{-1}	0.97 (0.92-1.01)	-1.4	0.16			
Pre-operative						
Creatinine; μmol.l^{-1}	1.00 (1.00-1.00)	1.9	0.052			
eGFR; ml.min^{-1}.1.73m^{-2}						
Haemoglobin; g.l^{-1}	1.00 (0.99-1.02)	0.8	0.45			
Lactate; mg.dl^{-1}	1.07 (1.01-1.13)	2.5	0.01			
Predicted monthly mortality; %						
Background	1.23 (1.10-1.38)	3.6	0.00034			
Postoperative						
P-POSSuM	1.02 (1.01-1.02)	4.2	< 0.001	1.01 (1.01-1.02)	3.85	0.00012
General model	1.01 (1.00-1.02)	2.8	0.0056			
Predicted median life expectancy; y						
Background	0.91 (0.87-0.96)	-3.4	0.00075			
'Postoperative'	0.92 (0.87-0.97)	-3.1	0.0022			

eGFR, estimated glomerular filtration rate.
*Likelihood ratio test 28.2, p = 0.000003; Wald test 25.0, p = 0.00002; Log-rank test 26.5, p = 0.000008.

Figure 1 Strobe diagram of 314 patients in whom emergency laparotomy was indicated. NELA, National Emergency Laparotomy Audit.

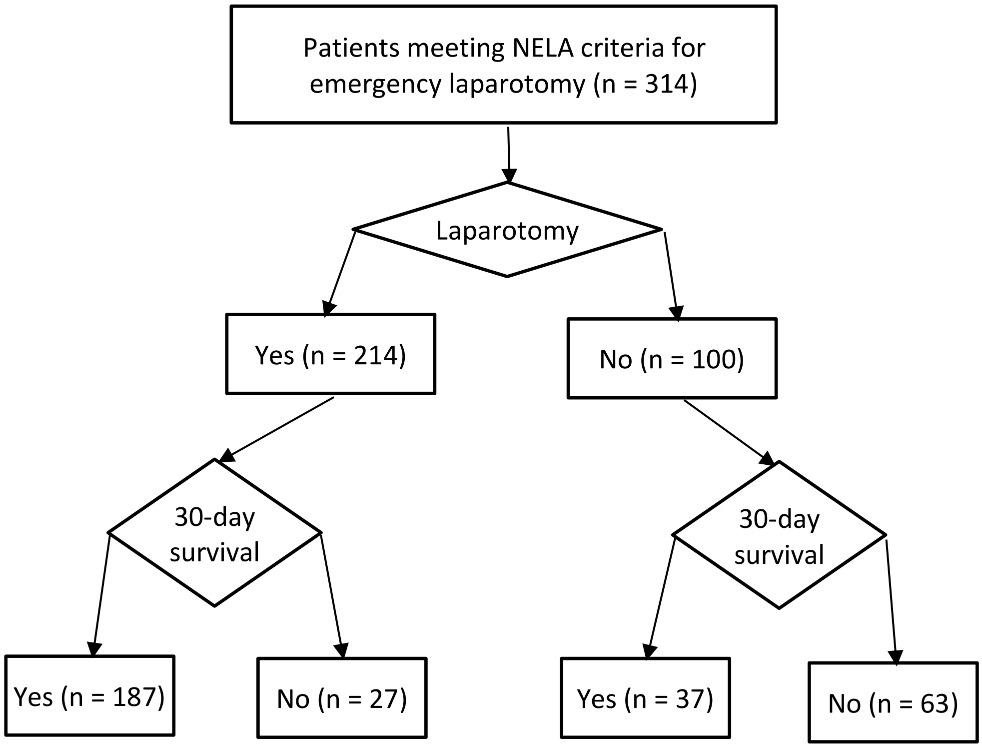


Figure 2 A histogram of median life expectancies in 314 patients admitted with acute surgical abdomen, 214 of whom had laparotomy (_____) and 100 of whom did not (____).

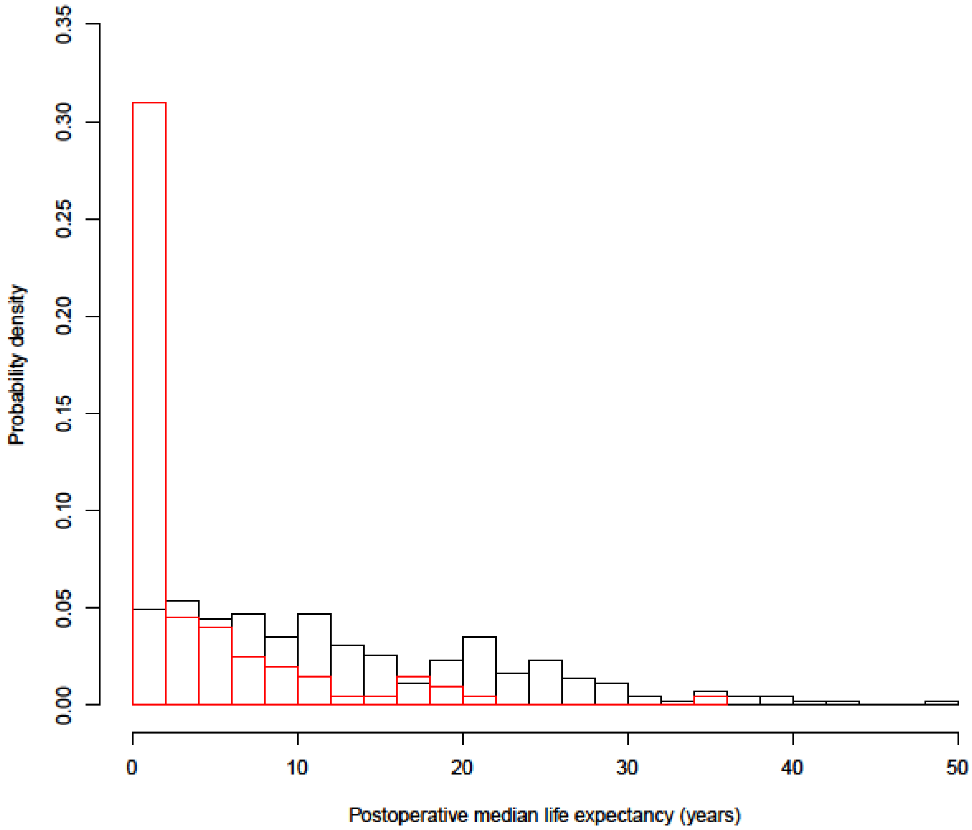
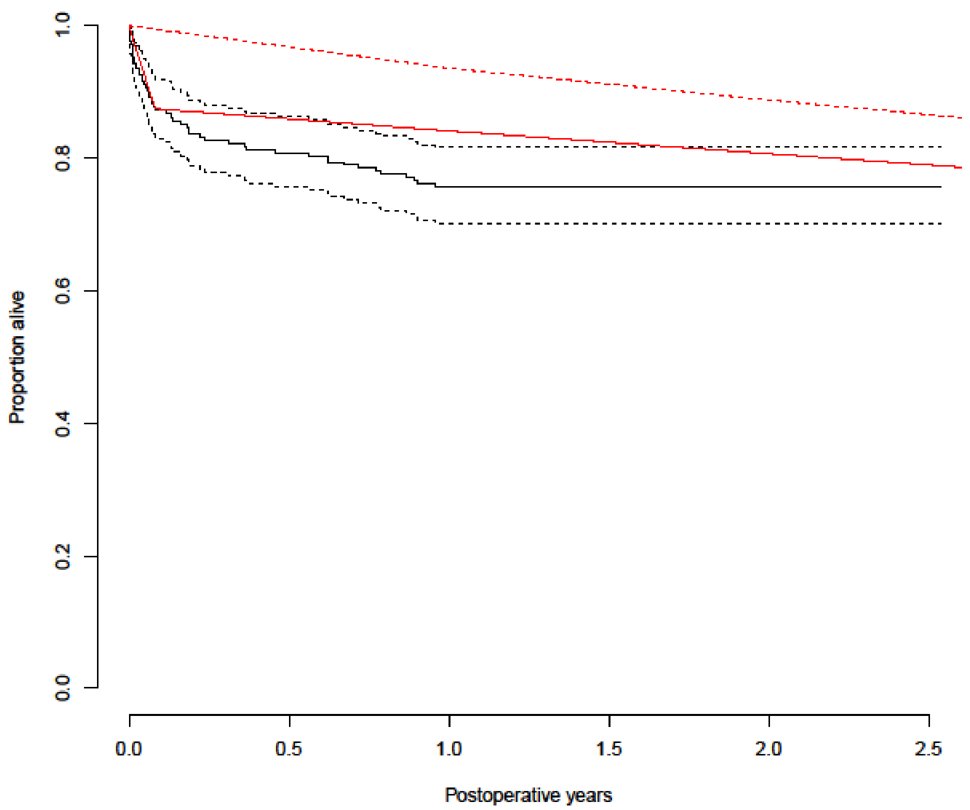


Figure 3 Observed survival (______) admission with acute surgical abdomen for 314 patients: a) 214 of whom had laparotomy; b) 100 of whom did not. Red lines are predicted survival after emergency laparotomy (______) and background survival without acute surgical abdomen (- - - - - - -). Dashed black lines are 95% CI.

a)



b)

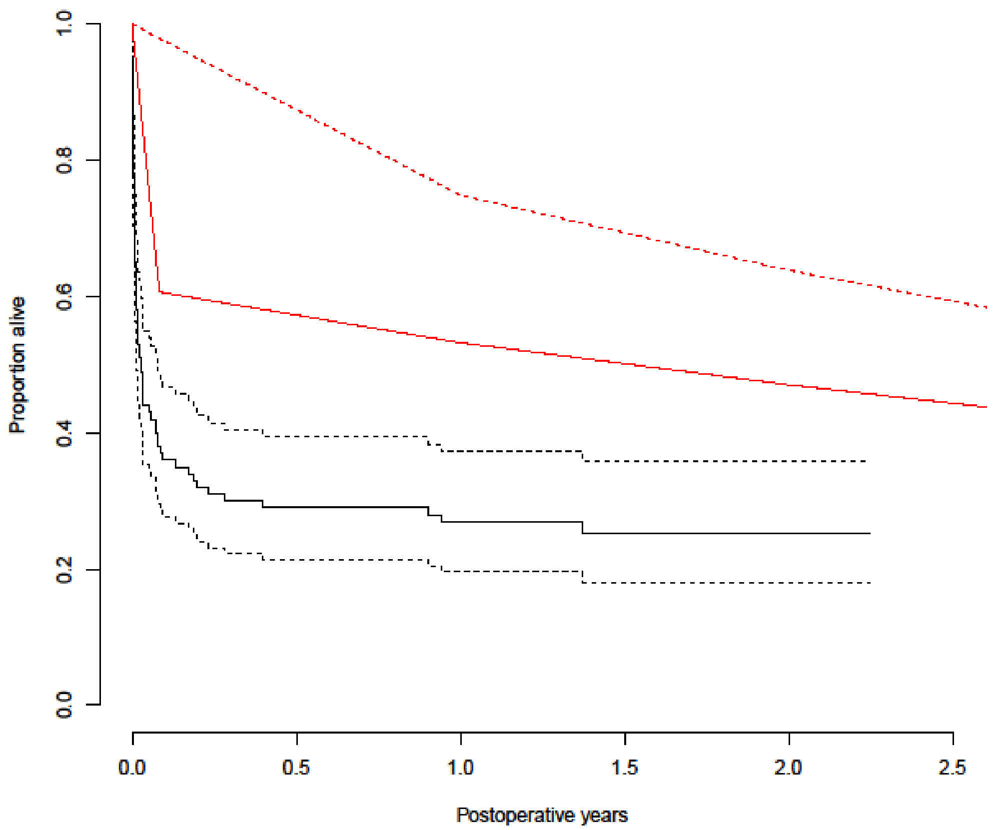
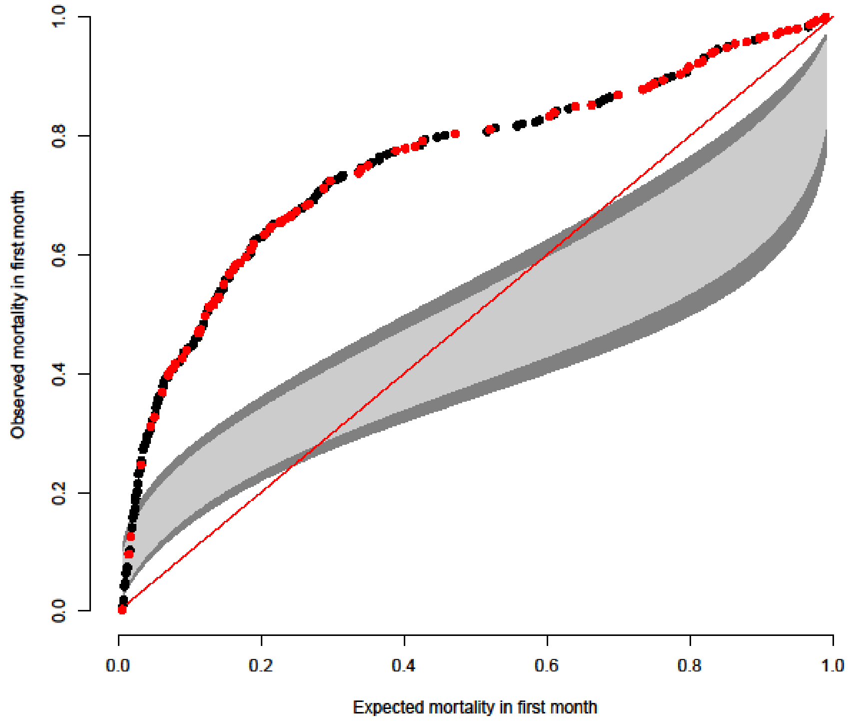
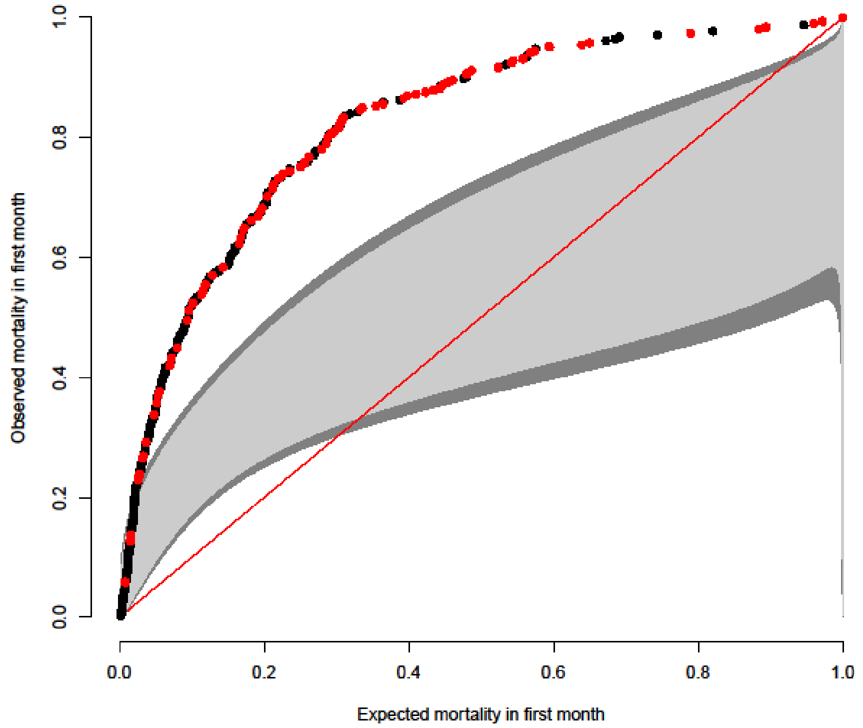


Fig. S1 Online supplementary information, composite graphs of: Giviti calibration belts for death within 30 days admission, with 95% and 99% confidence intervals; and cumulative distributions of predicted mortality for patients who survived (●) or died (●): a) Total cohort vs P-POSSuM; b) Total cohort vs general model; c) Laparotomy patients vs P-POSSuM; d) Laparotomy patients vs general model; e) Patients who did not have surgery vs P-POSSuM; f) Patients who did not have surgery vs general model.

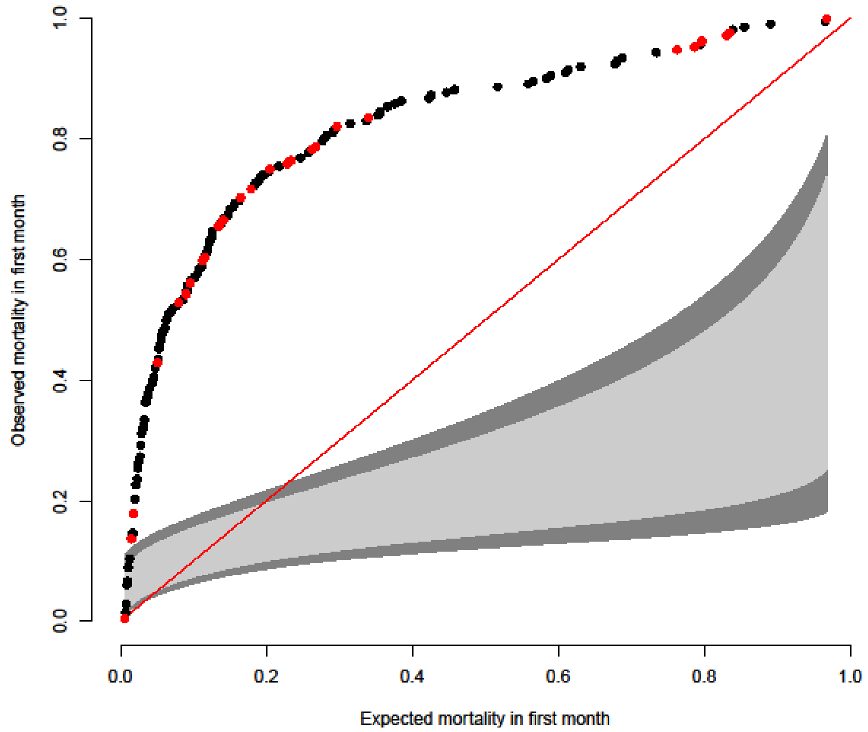
a)



b)

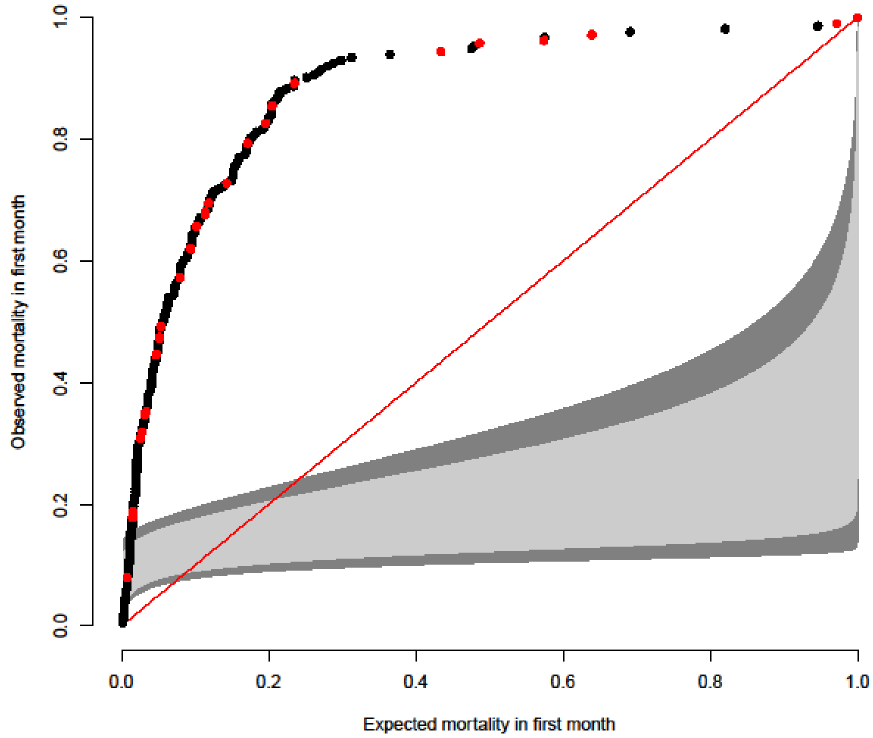


c)



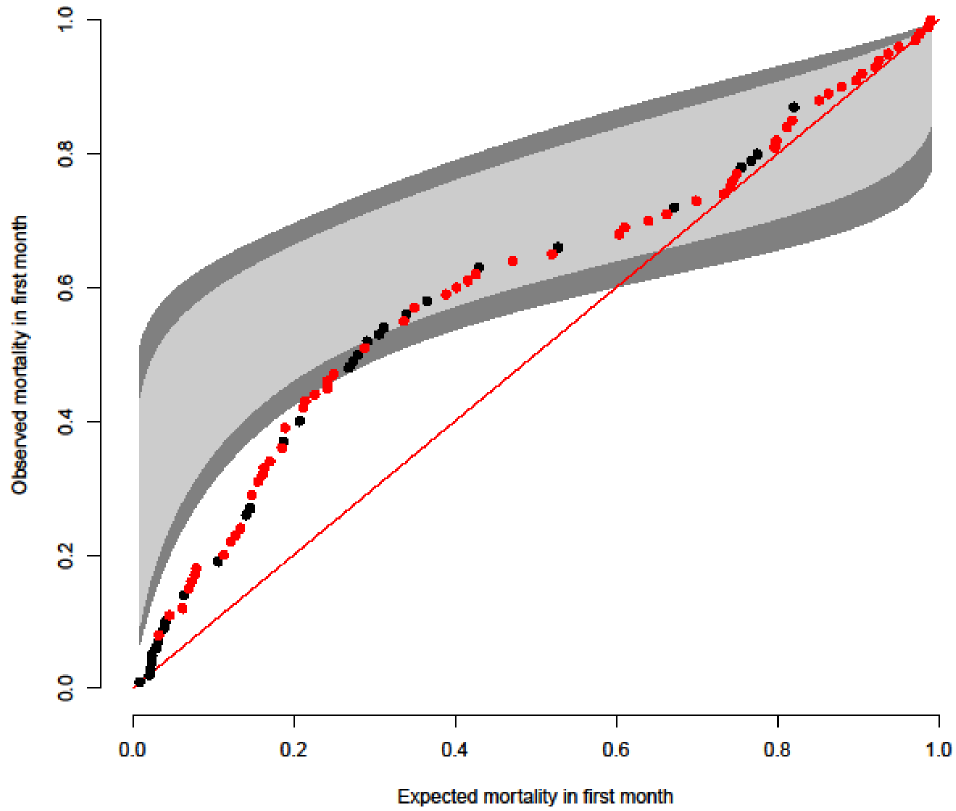
Observed mortality in first month
0.0
0.2
0.4
0.6
0.8
1.0
Expected mortality in first month

d)



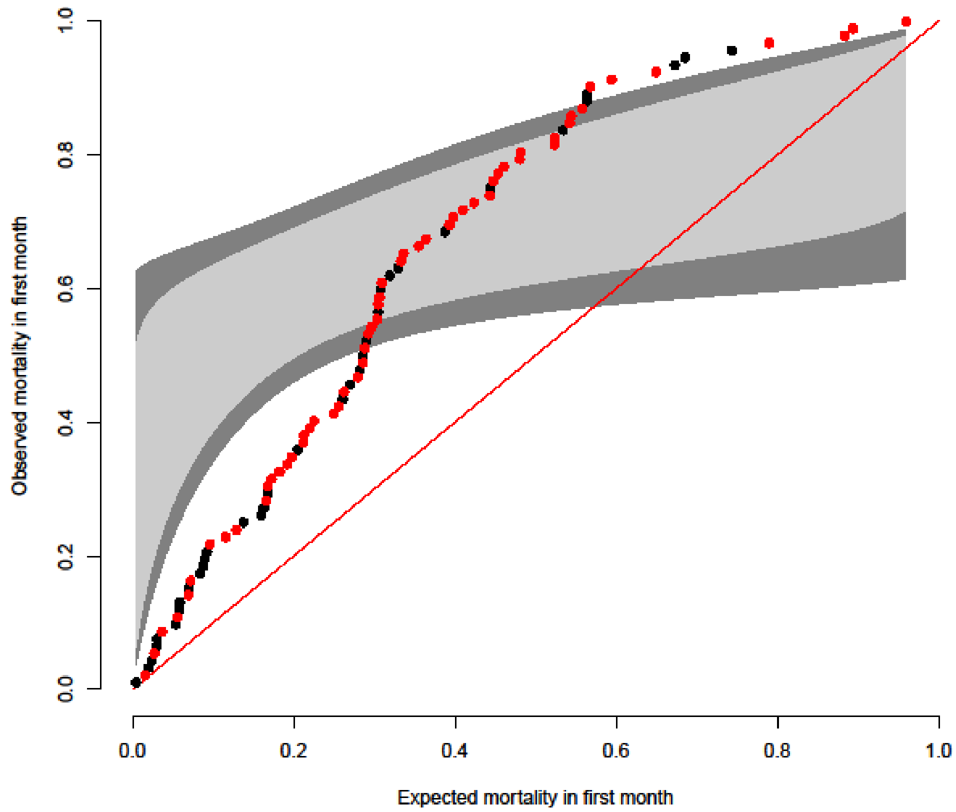
Observed mortality in first month
0.0
0.2
0.4
0.6
0.8
1.0
Expected mortality in first month

e)



1.0
0.8
0.6
0.4
0.2
0.0
Observed mortality in first month
0.0
0.2
0.4
0.6
0.8
1.0
Expected mortality in first month

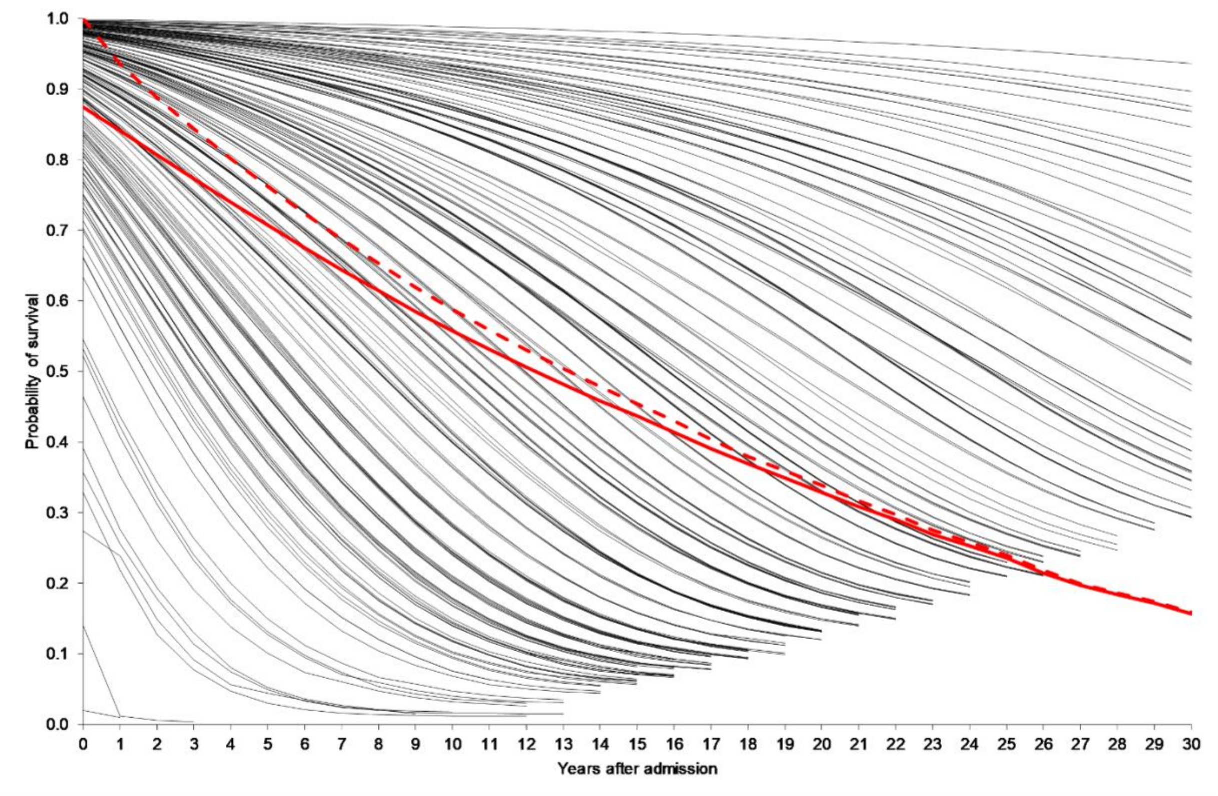
f)



1.0
0.8
0.6
0.4
0.2
0.0
Observed mortality in first month
0.0
0.2
0.4
0.6
0.8
1.0
Expected mortality in first month

Fig. S2 Predicted survival for 314 patients (____): a) 214 of whom had emergency laparotomy; b) 100 of whom did not. The average predicted survival with acute surgical abdomen (____) and without (- - - - - -).

a)



b)