Innovating for Improvement

Providing clear insight into patients' clinical and social care needs by a novel use of combined hospital datasets

East Kent Hospitals University NHS Foundation Trust

Centre for Health Services Studies, University of Kent

The
Health
Foundation

Project title:

Providing clear insight into patients' clinical and social care needs by a novel use of combined hospital datasets

Lead organisation:

East Kent Hospitals University NHS Foundation Trust, Ethelbert Road, Canterbury, Kent CT1 3NG

Partner organisation(s):

Centre for Health Services Studies, George Allen Wing, University of Kent, Canterbury, Kent CT2 7NF

Project lead(s):

Professor Chris Farmer
Dr Michael Bedford
Dr Paul Stevens

Contents

Part 1: Abstract

The primary aim of this project was to improve patient care delivered in the acute setting by streamlining the non-elective patient pathway. This was achieved by providing clinical staff with real time alerts to mobile devices. These alerts take three forms, critical information (e.g. lactate, NEWS score or AKI), composite alerts (e.g. evidence of sepsis) and "nudges".

Our project is innovative because it combines hospital datasets in real time, identifies critical information and provides context to the results such as links to published literature. The information was delivered direct to mobile devices using cloud computing, thus negating the need for access to NHS network. The evaluation included quantitative and qualitative elements.

The main successes of the project included avid uptake of the alerts, an impact on working practices from reactive to proactive working. One key benefit was staff members using the alerts to plan their workload such that patients were reviewed in the day according to clinical need. We did not demonstrate quantitative improvement in outcomes; this was to be expected due to the size and nature of the project.

The main challenge of the intervention was its complexity particularly relating to updating IT systems. Quality improvement approaches may be difficult to implement with short timelines when changes require updating IT systems. When considering a QI programme using informatics, timelines should be realistic.

The system has been embedded in the trust, further work is needed to embed this additional functionality across a complex organisation.

Part 2: Progress and outcomes

The primary aim of this project was to improve patient care delivered in the acute setting by streamlining the non-elective patient pathway. We wanted to achieve this by providing doctors, nurses and allied health professionals with predicted clinical outcomes based on data available on trust computer systems. Originally we aimed to match patients against previous admissions using a number of criteria for example, age, gender reason for admission, co-morbidity, physiological parameters and blood results. These predicted outcomes were to be delivered to mobile devices in real time.

During the course of the project it became clear that it would be very difficult to tease out the impact of such a complex intervention we therefore decided to adopt a step-wise approach to intervention.

1. Standard Alerting – provision of critical alerts for clinical parameters including; Acute Kidney Injury (AKI), Physiological Scoring / Early Warning Scores and laboratory variables such as lactate, critical potassium levels or haemoglobin levels. These alerts were sent to all members of the clinical team or outreach teams such as critical care outreach. No additional commentary or context was provided with these alerts.

2. Nudge Alerts – using published literature we provided insight into the implications of alerts provided via the system.

   We used "nudge" theory to influence clinical staff by providing context to clinical alerts based on the currently published literature. Briefly a "nudge" is any aspect of the choice architecture that alters people's behaviour in a predictable way without forbidding any options. To count as a mere nudge, the intervention must be easy to avoid. Therefore no recommendations were included with the information provided, existing alert systems and policies remain in place.

   This phase concentrated on four specific clinical scenarios (or combinations of scenarios), abnormal blood lactate, acute kidney injury, markers of sepsis and physiological scores (such as NEWS, NEWS2 etc.).Some examples are provided in Appendix 1.

   Brief messages were included with alerts such as raised lactate, NEWS etc. highlighting the potential implications of the abnormality seen. The messages will include a brief URL provided by Google URL shortener, (https://goo.gl/) allowing the user to quickly access the reference article. Only open access articles will be used. Google URL shortener also allows a count of the number of times each link has been used. Unfortunately during the course of the project google announced withdrawal of this service on 31st March 2019. We have developed plans to produce an alternative system so that the project is

sustainable in the long term.

3. Contextual alerts using historical admission data.
   Originally we aimed to have a third phase of implementation and testing using historical data. During the course of the project we encountered problems with access to data, this was mainly due to a delayed implementation of a new trust patient administration system (PAS). Using the learning from this project particularly with respect to operational barriers to implementation we aim to embark on this project next year.

We implemented the project on three general medical wards across the Trust, Sandwich Bay, Minster (subsequently Quex) and Deal wards which represent respiratory, gastroenterology, endocrinology, care of the elderly and general medical patients.

We monitored impact in a number of ways, variables we extracted from the hospital data warehouse are listed in Appendix 1. Other process measures included appropriate escalation, timely medical review, access to critical care outreach, delivery of sepsis 6 and AKI bundle, recording of ceilings of treatment and resuscitation events. A qualitative evaluation of the impact of the delivery of such data was performed at the end of the intervention including face-to-face interviews and focus groups. Progress reports were provided bi-monthly to the deteriorating patient group who reported to the patient safety board. Some of our original measures occurred so infrequently that we elected not to pursue measurement e.g. resuscitation events. We publicised the project through posters and grand round events (Appendix 1).

We were always aware that having a measureable quantitative impact in the context of a short study on three wards would be challenging particularly when a number of other initiatives and changes were occurring in the organisation (Sample SPC Run charts for key metrics are included in Appendix 1).

Broadly the alerts were received positively by clinicians, with support for the concept which was widely touted as "interesting," and initial expressions of utility *"it is very helpful to know who is unwell",* and convenience, *"I prefer [blood] results to come straight to my pocket."*

The alerts have been used imaginatively. Unintended uses which have emerged are doctors using the alerts to keep aware of deterioration amongst their more distant patients on outlying wards, and checking any overnight alerts first thing in the morning to help focus on which patients are a clinical priority for the morning ward round.

The main limitation to the standard alerts is alert fatigue, defined in one study as "the mental state that is the result of too many alerts consuming time and mental energy, which can cause important alerts to be ignored as well as clinically unimportant ones." (Coleman, van der Sijs et al. 2013). Alert fatigue was the most commonly

cited reason that we encountered for clinicians either permanently or temporarily disengaging from the project; its impact is clearly summarised by one clinician who admitted that, *"I keep turning them off, there are too many."* Fatigue only occurred in relation to NEWS alerts which repeat frequently if a patient becomes critically unwell and may continue despite appropriate medical intervention.

A number of improvements to the software have already been identified which we can incorporate into future iterations of the project, for example simplifying the NEWS alert formatting and expanding the digital functionality of the app to enable swiping, archiving and muting.

In some instances clinical behaviour may not have changed as a result of standard alerting, and a few individuals commented on this explicitly, for example, *"I'm not sure I have changed my response to sick patients."*

Part 3: Cost impact

During the course of the project we produced a business plan to continue to use the Careflow application at the acute hospital trust, coupled with this we piloted the use of the application in the community trust. Careflow is now part of business as usual in the acute trust and we have secured funding from NHS England via the Kent and Medway sustainability and transformation partnership (STP) to test the application further in the community concentrating on long term conditions and frailty.

We have not secured further funding to pursue further coding (programming) to produce more "nudge" alerts but are actively pursuing funding sources. We have a Darzi fellow (https://www.kssahsn.net/darzi-fellowship/Pages/default.aspx) working with the team until May 2019 who will continue with qualitative and quantitative evaluation.

We did not perform a formal financial evaluation or health economic evaluation of the impact of this project this was because it was an exploratory project trying to establish the best approach to communication in this setting. On-going cost of the additional alerting functionality produced by our project will be minimal. Additional costs of continuing the project will be further coding, estimated as a band 7 0.5 WTE, project management, application management and engagement will continue as part of business as usual across the entire trust. We will continue to evaluate the impact it has on the acute pathway through the deteriorating patient group and patient safety board.

Because of lack of measurable impact on outcomes we cannot be sure that the intervention will be cost saving, however given the limited ongoing cost of this additional functionality it is likely to be cost neutral.

Part 4: Learning from your project

The process for alerting has been established and the software application has been widely disseminated across the Trust as junior doctors rotate around different departments.

Our project was complex and had a lot of dependencies requiring development of alerting systems, buy-in from staff working on acute medical wards and support from informatics. We did not achieve all we hoped but because we changed the protocol early on in the project we gained considerable learning and have implemented a working system. We have plans to continue the project beyond the duration of this particular funding stream and have secured longer term funding both for business as usual as well as further pilots.

We were lucky enough to have a Darzi fellow (Dr Hannah Al-Hasani) helping us with the project as part of her secondment to East Kent Hospitals. This was hugely helpful in ensuring good engagement, particularly from medical and nursing staff.

The use of the hubs at our hospital sites enabled wider communication with staff. We had a very close relationship with the informatics department who supported and enabled the change.

Reporting directly to the Deteriorating Patient Group and ultimately the Patient Safety Board meant that the project had support at the highest level in the organisation.

The biggest barrier to delivery of the project was access to staff with the appropriate skills in coding, this was due to a changeover of the hospital patient administration system and more pressing tasks took priority. As a result we had to appoint a new computer programmer to complete the coding, introducing a delay to the project.

There have been a number of challenges so far.

- There are couple of technical issues within the Careflow application itself-

  o The NEWS alerts were difficult to interpret due to clumsy formatting, this has been resolved.
  o We had some issues with the reliability of the AKI and NEWS alerts which introduced anxiety amongst clinicians. This issue has been resolved.
  o Mapping patients to the doctors caring for them was complex, mainly because of different working practices across the three sites. This raised problems regarding workload, accountability and alert fatigue.

- Operational changes during the course of the project made implementation challenging. These include one of the pilot wards relocating geographically

within the hospital and a key Trust IT system changing. Realistically the acute health sector will always be volatile and so these are inherent conditions within which innovation and quality improvement must integrate and flourish.

- There has been a delay in software programming for the second stage of the project involving the delivery of contextualised alerting. This is due to conflicting workload pressures on the IT department which may reflect a lack of dedicated resource for digital innovation more generally within healthcare. This problem was overcome by appointing a dedicated programmer for the project but this introduced a delay.

- Alert fatigue has been a significant challenge and was predicted from the outset. A decision was made not to mitigate against them from the outset but to observe the problems directly so that appropriate solutions could be found. For example, NEWS alerts are a big problem but a second national iteration of the score is being released nationally (NEWS2) which may solve the problem, otherwise the score threshold for alerting may be increased to reduce the number of patients reaching it.

- A large number of wider issues regarding the "way we work" have been revealed. For example, the distribution of patients within the hospital is complicated and differs between specialities, departments and hospitals within our multi-site Trust. This is makes directing alerts to the correct clinician difficult. Another example is the high degree of variability among clinicians with respect to who takes clinical responsibility for a deteriorating patient, for example some would consider it is appropriate for the doctor who is physically nearest to the patient at that time, whereas others may consider the most junior or the most senior doctor on the patient's designated team the best option. These issues are not simple to resolve but impact significantly on how the alerts are used which inevitably will inform how they develop and evolve to be as useful as possible.

Part 5: Sustainability and spread

Assuming that the contextualised alerts continue to be received positively and there is sustained evidence of a positive change in clinical behaviours, the aim would be to spread the initiative more widely across all medical wards and eventually into other divisions such as general surgery and orthopaedic surgery. However, spread to surgical specialties will require development of alerts specific to surgical patients. Adverse events (e.g. AKI or Sepsis) are uncommon in elective surgical patients we will need to design alerting systems relevant to this patient group.

We have support from the patient safety group and Informatics and have secured funding to roll out this intervention across the organisation. The platform is in use by over 20 other acute hospital trusts, this functionality could be made available to all of these organisations making spread across the NHS a viable outcome and the results will be presented to the clinical engagement group for the application.

The project is established within the Kent, Surrey and Sussex Academic Health Studies Network, where contacts within another Trust which is also using Careflow alerting have been made. The intention is to collaborate and share results for spreading innovation via this route in the future.

The innovation has been presented both locally within the Trust and regionally at a Deteriorating Patient Collaborative group and has received interest and support in both areas. Further data are required before the project is broadcast more widely, and a national platform is certainly the intent once more results are available.

In terms of the evolution of the concept over time, the project was set up under a Patient Safety umbrella, focussed on the deteriorating patient. Since then, emerging uses such as checking alerts in the mornings introduce a less reactive and more proactive approach to clinical decision making, which is focussed less around the relative emergency situation of physiological derangement, and more on advanced care planning for all patients at risk of deterioration. There is therefore the potential to use alerting more diversely for example in conjunction with new ReSPECT documentation for end of life care planning.

Our Darzi fellow will test further iterations of our algorithm until March 2019. Further funding will need to be secured to develop and test the algorithms after this date. We plan to collate and publish our findings in April 2019.

We plan to implement this innovation between healthcare organisations including the community trust and primary care, this project is due to start in early 2019 and has secured funding from NHS England for one year.

Appendix 1: Resources and appendices

## Section a. Variables used to monitor the impact of clinical alerting across medical wards.

Non-elective admissions only

Between 1st January 2017 and 1st January 2019

- Date of admission
- Date of discharge
- Length of stay
- Increase in social care following discharge (for example admitted from residential home and discharged to nursing home)
- Acute kidney injury, worst during admission and change in AKI stage
- Readmission within 30 days
- Escalation of care to ITU
- Early warning score, peak during admission
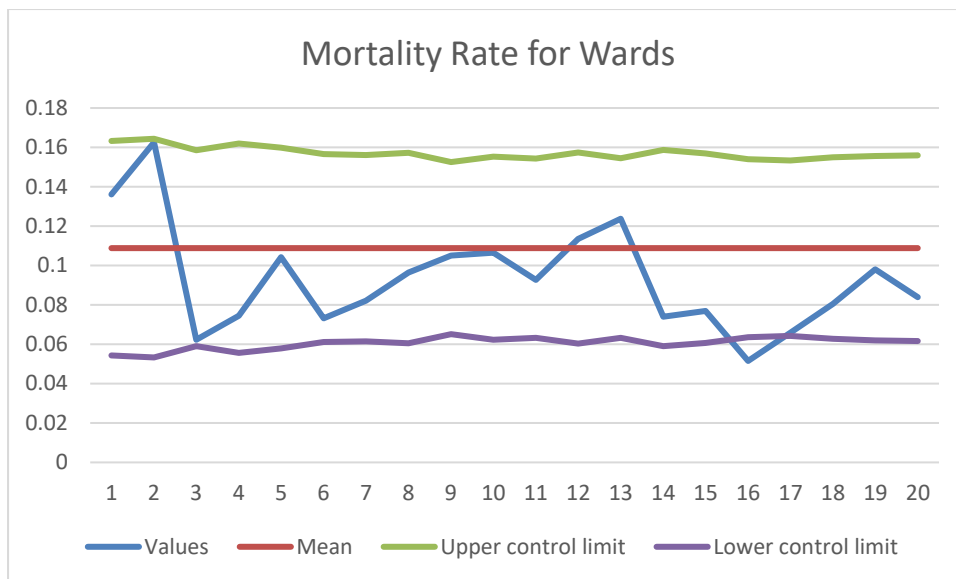- Resuscitation rates

Section b. Sample SPC run charts

SPC Run Chart for Escalation to ITU from Intervention Wards
(p chart)
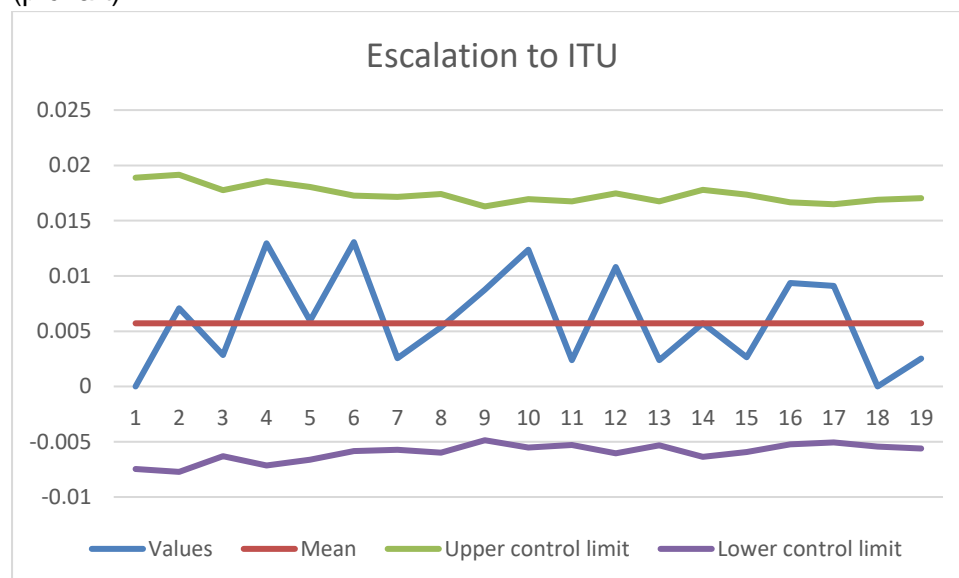
Initial intervention at Month 14

Numbers of admissions to ITU too small to adequately evaluate

Mortality Rate for Wards

Intervention at Month 14
(p chart)

Section c. Sample "soundbites" for alerts

1. *Lactate and emergency admission*

"About a third of patients (38%) with signs of infection and a lactate of 4mmol/l or more die within 28 days of presentation" (https://goo.gl/iAf3fc)
https://ac.els-cdn.com/S0196064404017494/1-s2.0-S0196064404017494-main.pdf?_tid=38a6e1a4-fa02-11e7-95c6-00000aacb362&acdnat=1516027491_4b227dfe56a5137b4eabf25c8f45d36d
Serum Lactate as a Predictor of Mortality in Emergency Department Patients with Infection Nathan I. Shapiro *et al.* **(2)**
Trigger: Lactate >4.0mmol/l AND sign of infection

"The combination of high lactate and CRP is associated with high mortality, 44% of people with infection, high lactate (≥4.0mmol/l) and CRP (>10mg/dl) die within 28 days"
http://www.sciencedirect.com/science/article/pii/S0196064410017099
Serum Lactate Is a Better Predictor of Short-Term Mortality When Stratified by C - reactive protein in Adult Emergency Department Patients Hospitalized for a Suspected Infection. Jeffrey P. Green *et al. (3)*
Trigger: Lactate>4.0 AND CRP >10mg/dl

 "More than 10% of patients with suspected sepsis and with lactate ≥2 mmol/L experience a prolonged ICU stay or died in hospital."
http://bmjopen.bmj.com/content/8/1/e015492.long
Serum lactate cut-offs as **a** risk stratification tool for in-hospital adverse outcomes in emergency department patients screened for suspected sepsis, Amith L Shetty *et al.(4)*
Trigger: Lactate >2mmo/l AND 2 of the following [APVU change, SBP ≤100mmHg, Resp Rate ≥22/min

"People admitted at night (5 pm to 7 am) with a high lactate (>4.0mmol/l) are more likely to have an unexpected transfer to ICU"
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5508707/

Unexpected intensive care transfer of admitted patients with severe sepsis. Wardi G *et al. (5)*
Trigger: Admission time 5pm to 7 am and Lactate ≥4mmol/l

"Critically ill patients in the emergency department are more than 20 times more likely to die in hospital if their lactate is greater than 4mmol/l than those with a normal lactate."
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5512839/
Serum lactate is an independent predictor of hospital mortality in critically ill patients in the emergency department: a retrospective study. Ralphe Bou Chebl *et al. (6)*
Trigger: Lactate ≥4 mmol/l

"Patients with a lactate of greater than 4mmol/l are 4-5 times more likely to die in hospital, develop acute kidney injury or need non-elective intubation or require vasopressor administration than those with a normal lactate regardless of the presence of infection"
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5305135/
Serum Lactate Predicts Adverse Outcomes in Emergency Department Patients With and Without Infection Kimie Oedorf *et al*. (7)
Trigger: Lactate ≥4 mmol/l

"If a high lactate fails to improve with initial treatment of critically ill patients outcome is significantly worse"
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4983759/
The value of blood lactate kinetics in critically ill patients: a systematic review. Jean-Louis Vincent *et al. (8)*
Trigger: Initial lactate ≥2mmol/l AND reference lactate ≥2mmol/l

"Additional monitoring may be appropriate in patients with a raised lactate (>2mmol/l) and acute coronary syndrome or myocardial infarction"
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4549782/
Clinical significance of lactate in acute cardiac patients. Chiara Lazzeri et al. (9)
Trigger: Raised Troponin (to be agreed) and lactate ≥2mmo/l

"Patients with sepsis or septic shock and a raised lactate (>4mmol/l) may benefit from serial lactate measurements in terms of more targeted care and clinical outcomes"
https://www.ncbi.nlm.nih.gov/pubmed/25186838
The impact of serial lactate monitoring on emergency department resuscitation interventions and clinical outcomes in severe sepsis and septic shock: an observational cohort study. Matthew Dettmer *et al. (10)*
Trigger: Lactate >2mmo/l AND 2 of the following [APVU change, SBP ≤100mmHg, Resp Rate ≥22/min]

"High lactate (>4mmo/l) in combination with markers of sepsis is associated with higher mortality (46% vs. 12%)"
https://www.ncbi.nlm.nih.gov/pubmed/28137926
Prognostic value of plasma lactate levels in a retrospective cohort presenting at a university hospital emergency department. van den Nouland DP *et al. (11)*
Trigger: Lactate >4mmo/l AND 2 of the following [APVU change, SBP ≤100mmHg, Resp Rate ≥22/min

    2.   Lactate and Surgery
"Raised lactate is associated with a high mortality in elderly patients (>70) following emergency laparotomy"
https://www.ncbi.nlm.nih.gov/pubmed/27783141

Emergency Abdominal Surgery in the Elderly: Can We Predict Mortality? Sharrock AE et al. (12)

Trigger: surgical admission AND Lactate ≥2mmol/l AND Age > 70 years

3. *Physiological Scoring*

"One in five patients with a NEWS score of 10 or above die, suffer unanticipated cardiac arrest or are admitted to ITU within 24 hours"

http://www.sciencedirect.com/science/article/pii/S0300957213000026

The ability of the National Early Warning Score (NEWS) to discriminate patients at risk of early cardiac arrest, unanticipated intensive care unit admission, and death. Gary B. Smith *et al.* (13)

Trigger: NEWS≥10

"A combination of a raised MEWS (≥7) and raised Lactate (>5mmol/l) predicts the need for ITU transfer in appropriate patients"

https://www.ncbi.nlm.nih.gov/pubmed/26161013

A combination of early warning score and lactate to predict intensive care unit transfer of inpatients with severe sepsis/septic shock. Yoo JW *et al.* (14)

Trigger: MEWS≥7 AND Lactate >5mmol/l

"Patients with a MEWS score of 3 or more are more likely to have unplanned ICU admissions [7% vs 1%], die in hospital [6% vs 1%], be readmitted within 30 days[19% vs 11%], and a longer length of stay [16 vs 6 days]."

https://www.ncbi.nlm.nih.gov/pubmed/27494719

A Protocolised Once a Day Modified Early Warning Score (MEWS) Measurement Is an Appropriate Screening Tool for Major Adverse Events in a General Hospital Population. van Galen LS *et al.* (15)

Trigger: MEWS≥3

"In a patient with a NEW score of 5 or more and a known infection, signs and symptoms of infection, or at risk of infection, think 'Could this be sepsis?' and escalate care immediately."

https://www.rcplondon.ac.uk/projects/outputs/national-early-warning-score-news-2

National Early Warning Score (NEWS) 2. Standardising the assessment of acute-illness severity in the NHS. Royal College of Physicians 2017. (16)

Trigger: NEW≥5 AND SOFA

"If a patient has signs of sepsis and an initial NEW score of 5 or 6 they have an 11% chance of death within a month"

Trigger NEW 5-6 AND SOFA

"If a patient has signs of sepsis and an initial NEW score of 7 or 8 they have an 13% chance of death within a month"

Trigger NEW 7-8 AND SOFA

"One in three patients with signs of sepsis and an initial NEW score more than 9 die within a month"

Trigger: NEW 9-20 AND SOFA note: an assessment of 60 consecutive acute admissions with signs of infection and a qSOFA score of 2 or more at University College London

Hospital found that, in every instance with a qSOFA score of 2 or more, there was a NEW score of 5 or more (SJ Gonzaga, personal communication, December 2016.

http://emj.bmj.com/content/31/6/482

Utility of a single early warning score in patients with sepsis in the emergency department. Alasdair R Corfield *et al. (17)*

4. *Acute Kidney Injury*

"Acute Kidney Injury following emergency surgery for fractured neck of femur is associated with 10% in-hospital mortality"
https://www.ncbi.nlm.nih.gov/pubmed/28426743
Acute kidney injury can predict in-hospital and long-term mortality in elderly patients undergoing hip fracture surgery. Hong SE *et al.* (18)
Trigger: Non-elective orthopaedic admission AND AKI [any]

"Patients with AKI 1-3 are two to three times more likely to have an unplanned readmission often due to pulmonary oedema (26%)"
https://www.ncbi.nlm.nih.gov/pubmed/28061831
Acute kidney injury as an independent risk factor for unplanned 90-day hospital readmissions. Sawhney S *et al.* (19)
Trigger: AKI [any]

"Patients with infective exacerbations of chronic lung disease who develop acute kidney injury have a 5 times more likely to die in hospital"
https://www.ncbi.nlm.nih.gov/pubmed/26787372
**Diagnosis of acute kidney injury and its association with in-hospital mortality in patients with infective exacerbations of bronchiectasis: cohort study from a UK nationwide database. Iwagami M *et al. (20)*

Trigger: Non-elective medical or care of the elderly AND AKI [any] AND SOFA

"Acute Kidney Injury following non-cardiac surgery is associated with increased mortality (5-fold) and longer hospital stay"
https://www.ncbi.nlm.nih.gov/pubmed/26492475
**Minor Postoperative Increases of Creatinine Are Associated with Higher Mortality and Longer Hospital Length of Stay in Surgical Patients. Kork F *et al. (21)*
Trigger: AKI [any] AND non-elective surgical admission AND operation this admission

"Acute kidney injury is commoner in patients with COPD. If people with an exacerbation of COPD develop AKI their outcome is worse"
https://www.ncbi.nlm.nih.gov/pubmed/26451102
**Acute kidney injury in stable COPD and at exacerbation. Barakat MF *et al. (22)*
Trigger: Non-elective medical admission and AKI [any] AND SOFA

"Patients with AKI 2 are more than 10 times more likely to die in hospital compared to those without AKI"
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4079645/pdf/1471-2369-15-95.pdf
What is the real impact of acute kidney injury? Michael Bedford *et al. (23)*
Trigger: AKI 2

"A third of patients with AKI 3 die in hospital"
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4079645/pdf/1471-2369-15-95.pdf
What is the real impact of acute kidney injury? Michael Bedford *et al. (23)*

Trigger: AKI 3

"Patients with AKI 2 or 3 have double the length of stay compared to those without AKI"
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4079645/pdf/1471-2369-15-95.pdf
What is the real impact of acute kidney injury? Michael Bedford *et al. (23)*
Trigger: AKI 2 OR 3

"A fifth of inpatients with AKI 3 are admitted to Intensive care"
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4079645/pdf/1471-2369-15-95.pdf
What is the real impact of acute kidney injury? Michael Bedford *et al. (23)*
Trigger: AKI 3

Section d. Sample publicity for the project

References

(1) Thaler RH, Sunstein CR. *Nudge: Improving Decisions about Health, Wealth, and Happiness*. 1st ed.: Yale University Press; 2008.

(2) Shapiro NI, Howell MD, Talmor D, Nathanson LA, Lisbon A, Wolfe RE, et al. Serum lactate as a predictor of mortality in emergency department patients with infection. Ann Emerg Med 2005 May;45(5):524-528.

(3) Green JP, Berger T, Garg N, Shapiro NI. Serum lactate is a better predictor of short-term mortality when stratified by C-reactive protein in adult emergency department patients hospitalized for a suspected infection. Ann Emerg Med 2011 Mar;57(3):291-295.

(4) Shetty AL, Thompson K, Byth K, Macaskill P, Green M, Fullick M, et al. Serum lactate cut-offs as a risk stratification tool for in-hospital adverse outcomes in emergency department patients screened for suspected sepsis. BMJ Open 2018 Jan 5;8(1):e015492-2016-015492.

(5) Wardi G, Wali AR, Villar J, Tolia V, Tomaszewski C, Sloane C, et al. Unexpected intensive care transfer of admitted patients with severe sepsis. J Intensive Care 2017 Jul 12;5:43-017-0239-7. eCollection 2017.

(6) Bou Chebl R, El Khuri C, Shami A, Rajha E, Faris N, Bachir R, et al. Serum lactate is an independent predictor of hospital mortality in critically ill patients in the emergency department: a retrospective study. Scand J Trauma Resusc Emerg Med 2017 Jul 14;25(1):69.

(7) Oedorf K, Day DE, Lior Y, Novack V, Sanchez LD, Wolfe RE, et al. Serum Lactate Predicts Adverse Outcomes in Emergency Department Patients With and Without Infection. West J Emerg Med 2017 Feb;18(2):258-266.

(8) Vincent JL, Quintairos E Silva A, Couto L,Jr, Taccone FS. The value of blood lactate kinetics in critically ill patients: a systematic review. Crit Care 2016 Aug 13;20(1):257-016-1403-5.

(9) Lazzeri C, Valente S, Chiostri M, Gensini GF. Clinical significance of lactate in acute cardiac patients. World J Cardiol 2015 Aug 26;7(8):483-489.

(10) Dettmer M, Holthaus CV, Fuller BM. The impact of serial lactate monitoring on emergency department resuscitation interventions and clinical outcomes in severe sepsis and septic shock: an observational cohort study. Shock 2015 Jan;43(1):55-61.

(11) van den Nouland DP, Brouwers MC, Stassen PM. Prognostic value of plasma lactate levels in a retrospective cohort presenting at a university hospital emergency department. BMJ Open 2017 Jan 30;7(1):e011450-2016-011450.

(12) Sharrock AE, McLachlan J, Chambers R, Bailey IS, Kirkby-Bott J. Emergency Abdominal Surgery in the Elderly: Can We Predict Mortality? World J Surg 2017 Feb;41(2):402-409.

(13) Smith GB, Prytherch DR, Meredith P, Schmidt PE, Featherstone PI. The ability of the National Early Warning Score (NEWS) to discriminate patients at risk of early cardiac arrest, unanticipated intensive care unit admission, and death. Resuscitation 2013 Apr;84(4):465-470.

(14) Yoo JW, Lee JR, Jung YK, Choi SH, Son JS, Kang BJ, et al. A combination of early warning score and lactate to predict intensive care unit transfer of inpatients with severe sepsis/septic shock. Korean J Intern Med 2015 Jul;30(4):471-477.

(15) van Galen LS, Dijkstra CC, Ludikhuize J, Kramer MH, Nanayakkara PW. A Protocolised Once a Day Modified Early Warning Score (MEWS) Measurement Is an Appropriate Screening Tool for Major Adverse Events in a General Hospital Population. PLoS One 2016 Aug 5;11(8):e0160811.

(16) London: RCP. Royal College of Physicians. National Early Warning Score (NEWS) 2: Standardising the assessment of acute-illness severity in the NHS. Updated report of a working party. 2017.

(17) Corfield AR, Lees F, Zealley I, Houston G, Dickie S, Ward K, et al. Utility of a single early warning score in patients with sepsis in the emergency department. Emerg Med J 2014 BMJ Publishing Group Ltd and the British Association for Accident & Emergency Medicine;31(6):482-487.

(18) Hong SE, Kim TY, Yoo JH, Kim JK, Kim SG, Kim HJ, et al. Acute kidney injury can predict in-hospital and long-term mortality in elderly patients undergoing hip fracture surgery. PLoS One 2017 Apr 20;12(4):e0176259.

(19) Sawhney S, Marks A, Fluck N, McLernon DJ, Prescott GJ, Black C. Acute kidney injury as an independent risk factor for unplanned 90-day hospital readmissions. BMC Nephrol 2017 Jan 6;18(1):9-016-0430-4.

(20) Iwagami M, Mansfield K, Quint J, Nitsch D, Tomlinson L. Diagnosis of acute kidney injury and its association with in-hospital mortality in patients with infective exacerbations of bronchiectasis: cohort study from a UK nationwide database. BMC Pulm Med 2016 Jan 19;16:14-016-0177-5.

(21) Kork F, Balzer F, Spies CD, Wernecke KD, Ginde AA, Jankowski J, et al. Minor Postoperative Increases of Creatinine Are Associated with Higher Mortality and Longer Hospital Length of Stay in Surgical Patients. Anesthesiology 2015 Dec;123(6):1301-1311.

(22) Barakat MF, McDonald HI, Collier TJ, Smeeth L, Nitsch D, Quint JK. Acute kidney injury in stable COPD and at exacerbation. Int J Chron Obstruct Pulmon Dis 2015 Sep 28;10:2067-2077.

(23) Bedford M, Stevens PE, Wheeler TW, Farmer CK. What is the real impact of acute kidney injury? BMC Nephrol 2014 Jun 21;15:95-2369-15-95.

(24) Prytherch DR, Smith GB, Schmidt PE, Featherstone PI. ViEWS--Towards a national early warning score for detecting adult inpatient deterioration. Resuscitation 2010 Aug;81(8):932-937.

(25) London:RCP. Royal College of Physicians. National Early Warning Score (NEWS) Standardising the assessment of acute-illness severity in the NHS. Report of a working party. 2012.

(26) Smith GB, Prytherch DR, Meredith P, Schmidt PE, Featherstone PI. The ability of the National Early Warning Score (NEWS) to discriminate patients at risk of early cardiac arrest, unanticipated intensive care unit admission, and death. Resuscitation 2013 Apr;84(4):465-470.

(27) Subbe CP, Kruger M, Rutherford P, Gemmel L. Validation of a modified Early Warning Score in medical admissions. QJM 2001 Oct;94(10):521-526.

(28) Gardner-Thorpe J, Love N, Wrightson J, Walsh S, Keeling N. The value of Modified Early Warning Score (MEWS) in surgical in-patients: a prospective observational study. Ann R Coll Surg Engl 2006 Oct;88(6):571-575.

(29) Singer M, Deutschman CS, Seymour CW, Shankar-Hari M, Annane D, Bauer M, et al. The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). JAMA 2016 Feb 23;315(8):801-810.