Received: 25 October 2019 | First decision: 24 November 2019 | Accepted: 18 April 2020

DOI: 10.1111/apt.15781

AP&T Alimentary Pharmacology & Therapeutics WILEY

Reducing variation in hospital mortality for alcohol-related liver disease in North West England

Constantinos Kallis[1] | Pete Dixon[1] | Benjamin Silberberg[1] | Lynn Affarah[2] | Mustafa Shawihdi[1] | Ruth Grainger[3] | Nancy Prospero[4] | Mike Pearson[1] | Anthony Marson[5] | Subramanian Ramakrishnan[6] | Paul Richardson[2] | Steve Hood[2] | Keith Bodger[1,2]

[1]Department of Health Data Science, Institute of Population Health Sciences, University of Liverpool, Liverpool, UK

[2]Digestive Diseases Unit, Liverpool University Hospitals NHS Foundation Trust, Liverpool, UK

[3]Arden and Greater East Midlands Commissioning Support Unit, Liverpool, UK

[4]Advancing Quality Alliance, Sale, UK

[5]Department of Molecular and Clinical Pharmacology, University of Liverpool, Liverpool, UK

[6]Gastroenterology, Warrington and Halton Hospitals NHS Foundation Trust, Warrington, UK

Correspondence
Keith Bodger, Department of Health Data Science, Institute of Population Health Sciences, University of Liverpool, Liverpool, UK
Email: kbodger@liverpool.ac.uk

Funding information
The Connected Health Cities (CHC) Programme is a Health North pilot project funded by the UK's Department of Health and delivered by the Northern Health Science Alliance. This work was funded by the UK Department of Health (Connected Health Cities programme) and delivered by the Northern Health Science Alliance. The funding sponsors had no role in the design and conduct of the study; in the collection, management, analysis and interpretation of the data; or in the preparation, review or approval of the manuscript.

Summary

Background: Variations in emergency care quality for alcohol-related liver disease (ARLD) have been highlighted.

Aim: To determine whether introduction of a regional quality improvement (QI) programme was associated with a reduction in potentially avoidable inpatient mortality.

Method: Retrospective observational cohort study using hospital administrative data spanning a 1-year period before (2014/2015) and 3 years after a QI initiative at seven acute hospitals in North West England. The intervention included serial audit of a bundle of process metrics. An algorithm was developed to identify index ("first") emergency admissions for ARLD (n = 3887). We created a standardised mortality ratio (SMR) to compare relative mortality and regression models to examine risk-adjusted odds of death.

Results: In 2014/2015, three of seven hospitals had an SMR above the upper control limit ("outliers"). Adjusted odds of death for patients admitted to outlier hospitals was higher than non-outliers (OR 2.13, 95% CI 1.32-3.44, P = 0.002). Following the QI programme there was a step-wise reduction in outliers (none in 2017/2018). Odds of death was 67% lower in 2017/2018 compared to 2014/2015 at original outlier hospitals, but unchanged at other hospitals. Process audit performance of outliers was worse than non-outliers at baseline, but improved after intervention.

Conclusions: There was a reduction in unexplained variation in hospital mortality following the QI intervention. This challenges the pessimism that is prevalent for achieving better outcomes for patients with ARLD. Notwithstanding the limitations of an uncontrolled observational study, these data provide hope that co-ordinated efforts to drive adoption of evidence-based practice can save lives.

The Handling Editor for this article was Professor Gideon Hirschfield, and it was accepted for publication after full peer-review.

1 | INTRODUCTION

Alcohol-related liver disease (ARLD) typically presents late and often with fatal complications. In the UK it is estimated that up to 75% of fatal liver cirrhosis is undetected before a patient's first hospitalisation.[1,2] Nevertheless, early inpatient intervention with evidence-based treatments has the potential to save lives.[3] However, variation in the provision, quality and consistency of inpatient care has been highlighted in several countries. In the UK in 2013, a report entitled "Measuring the Units" from the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) showed suboptimal care for patients dying during a hospitalisation for ARLD.[4] Only 47% of cases were judged to have received "good care" in hospital and potentially avoidable deaths were identified. A year later, the *Lancet Commission* highlighted wide variation in inpatient mortality, describing a "postcode lottery of liver services"[2] and a parliamentary group raised "grave concerns" about patchy provision of high-quality specialist care.[5] A follow-up report included a comparative analysis of administrative data for in-hospital mortality for non-elective admissions for "liver disease" across 134 English hospitals (2014-2018), suggesting more than twofold variation both in crude mortality (range: 6%-16%) and standardised mortality ratio (SMR ranging from approximately 60-140) across providers.[6] Specific data for ARLD were not presented. Evidence of inconsistent acute care for patients admitted to US hospitals with decompensated liver disease were reported in 2012[7] and 2014.[8]

There has been progress in defining candidate process measures to help identify variations in key aspects of care and support quality improvement (QI).[9–12] However, no real-world evidence has emerged for QI programmes leading to reductions in avoidable hospital mortality. In 2016, Dyson et al reported an initiative for decompensated cirrhosis from three English hospitals.[13] Responding to NCEPOD recommendations, the authors introduced a "liver bundle" to promote best practice and undertook audits of care before and after efforts to implement it. Alcohol was the underlying cause of cirrhosis in 85% of cases. After roll-out, the bundle was completed in 59% of 136 patients and these cases had significantly higher rates of early diagnostic ascitic tap, antibiotic prescribing and documentation of alcohol consumption. Overall mortality was 15%, but the study was unable to detect significant reduction in death rate over time, nor demonstrate a lower rate of mortality for patients with a completed bundle. An editorial expressed frustration that despite a successful effort to implement a policy promoting early delivery of evidence-based care, evidence for improvement in the "hard end-point" of survival was lacking.[14] The commentary suggested that future evaluations of QI interventions needed to include centres where in-hospital mortality was "unusually high."

The North West region of England has one of the country's highest rates of alcohol-specific deaths and ARLD is the dominant cause.[15] In early 2015, the Advancing Quality Alliance launched a regional QI programme focused on improving emergency hospital care for ARLD. We report a retrospective analysis of time trends in inpatient mortality across seven participating hospitals, using independent administrative data to examine whether the programme was associated with a reduction in unwarranted variation in deaths during emergency admission for ARLD. This work was part of the North West Coast Connected Health Cities programme, a publicly funded regional health informatics initiative aimed at enhancing analysis of routine healthcare data to support establishment of learning healthcare systems.[16]

2 | METHODS

2.1 | Study design

This was a retrospective observational cohort study using routinely collected, anonymised administrative data for the period 2014/2015 to 2017/2018.

2.2 | Setting

Seven acute hospitals in the North West region of England that participated in a regional QI programme.

2.3 | The Advancing Quality intervention

Advancing Quality (AQ) is a care programme operated by the Advancing Quality Alliance (AQuA) which delivers a range of services to NHS healthcare organisations across the North West of England.[17] The programme offers members a structured approach to embedding evidence-based care with the aims of improving health outcomes while reducing unwarranted variation in the care of highly prevalent conditions. Prior to launch of each programme, a local Clinical Expert Group reviews evidence and identifies a set of condition-specific interventions known to improve outcomes along with a set of process measures to allow benchmarking of care ("AQ measures"). The AQ programme includes continuous audit of samples of admissions to monitor hospital-level performance against AQ measures, with transparent monthly reporting and a series of regional QI meetings of participating teams. The QI initiative was also supported by an optional financial incentive scheme (Commissioning for Quality & Innovation, CQIN) during 2015/2016 to 2016/2017, whereby local service commissioners could assign a small proportion of contracted payments to acute hospitals for participation.[18] The programme for ARLD was launched in 2015, with an original set of 11 AQ measures collected.[19] The measures focused on the early detection and management of complications linked to in-hospital mortality (eg spontaneous bacterial peritonitis and variceal bleeding) as well as triage to correct ward and early specialist hepatology input (Table 5). Review of AQ measures by the Clinical Expert Group in 2017/2018 resulted in refinement of some definitions, merger or retirement of selected process measures (to simplify data collection or remove metrics that were no longer required), resulting in seven process metrics.

2.4 | Data sources, information governance and ethics

Complete administrative data were available for seven participating hospitals for the period 2013/2014 to 2017/2018. The dataset is equivalent to Hospital Episode Statistics, as previously described.[20] We focused our analysis on admissions in the year before the AQ programme was launched (2014/2015) and three consecutive fiscal years after the intervention (2015/2016 to 2017/2018). Data for 2013/2014 were used as screening period to enable identification of index ("first") admissions for ARLD (see cohort selection below). This work formed part of a service evaluation and improvement programme and made use of anonymised administrative data with approval from NHS Digital, hence ethical approval was not required. Benchmarking reports based on our analyses of administrative data were shared with hospital teams in August 2019.

Aggregated hospital-level information relating to serial local audits was provided by AQuA, including data collected during the first 3 months of the AQ programme when teams received their first (baseline) reports of audit performance, and data from the latest available comparable 3-month period within the time frame of our analysis of administrative data (January-March 2018).

2.5 | Cohort selection

2.5.1 | Development and validation of diagnostic coding algorithm

The standard approach for identifying admissions within administrative data is to focus exclusively on the primary (principal) discharge diagnosis code. However, ARLD is a complex condition and can present with a spectrum of symptoms, signs, specific disease complications and with other co-existing alcohol-related disorders. Inadequate identification of liver-related admissions based on primary diagnosis alone has been reported.[21] Hence, we needed to develop a better method for identifying cohorts of people with ARLD and their relevant emergency admissions from administrative data. Each care episode contains up to 23 diagnostic codes, classified according to version 10 of the International Classification of Diseases (ICD-10).

Using the regional dataset for all-cause admissions, we set out to define patterns of diagnostic codes consistent with acute presentations of ARLD (Table 1). First, we flagged admissions with any of the six specific codes for ARLD recorded as primary diagnosis (Table S1)—referred to as ARLD-Primary admissions and reflecting the standard approach. Next, we extracted admissions where such codes appeared in a nonprimary position and created frequency tables of the primary diagnoses recorded for those admissions. Two clinicians reviewed the tables independently, selecting primary codes compatible with emergency presentations of ARLD. Any discrepancies were resolved by informal consensus. This resulted in one code list for "symptoms, signs or complications" of ARLD (eg jaundice, ascites, oesophageal varices, acute kidney injury, infections/sepsis, encephalopathy; Table S2) and another for "other alcohol-specific conditions" (eg acute alcohol withdrawal or alcoholic gastritis; Table S3). Primary codes were rejected when judged to indicate that ARLD was not the main reason for admission (eg chronic obstructive airways disease).

We also identified other categories of admission where a code for nonspecific liver disease (eg other and unspecified cirrhosis of the liver; Table S4) co-existed with a code for an alcohol-specific condition—thereby suggesting the liver disease was alcohol related. Using the clinician-generated list for symptoms, signs and complications, we defined which of these admissions were also eligible for inclusion. An algorithmic procedure was created to screen the dataset to identify admissions with any of the permitted coding combinations, referred to collectively as ARLD-Algorithm admissions. This included ARLD-Primary admissions plus the extra admissions identified from alternative coding patterns (ARLD-Uplift).

Algorithm performance was evaluated at one hospital as part of an audit of care by two independent clinician observers (BS and LA), each reviewing a series of consecutive patients (n = 49 and n = 48 respectively) who had been referred to alcohol services during an emergency admission. Review of manual and electronic records established whether or not the admission was related to acute management of ARLD with the two reviewers blinded to discharge

TABLE 1 Summary of diagnostic coding algorithm to identify admissions for alcohol-related liver disease (ARLD) within the administrative dataset. Each care episode in the dataset contains up to 23 diagnostic codes assigned by clinical coders after discharge, using the International Classification of Diseases 10th Revision (ICD-10) system. See Supporting information for full code lists.

The list of ICD-10 codes must conform to one of four patterns:
1. ARLD-specific code[a] recorded as primary diagnosis (ARLD-Primary)
2. ARLD-specific code recorded as a secondary diagnosis
All higher order diagnoses must be either:
(A) Symptom, sign or complication[b], or
(B) Other alcohol-specific diagnosis[c]
3. Nonspecific liver disease code[d] recorded as a primary diagnosis
Lower order diagnoses must include one alcohol-specific diagnosis
4. Nonspecific liver disease recorded as a secondary diagnosis
All higher order diagnoses must be either:
(A) Symptom, sign or complication, or
(B) Other alcohol-specific diagnosis (at least one must be recorded)

[a]Six specific codes for alcohol-related liver disease (see Table S1).
[b]Codes for jaundice, ascites, varices, acute kidney injury, encephalopathy and other relevant diagnoses suggesting admission for ARLD complications (see Table S2).
[c]Codes for other alcohol-specific conditions such as alcohol intoxication, withdrawal and organ-specific disorders (eg alcoholic gastritis; see Table S3).
[d]Codes for liver disease without specific aetiology (eg cirrhosis, unspecified; see Table S4).

coding. Thirteen ARLD admissions were identified among the 97 cases. Discharge codes were then extracted and admissions classified by the primary and algorithm methods. We confirmed that ARLD-Primary approach had excellent specificity (100%) but poor sensitivity for detecting all relevant liver-related admissions (only 61.5%), whereas the algorithm had much better sensitivity (92.3%) while retaining high specificity (91.7%).

2.6 | Defining index admissions for ARLD

We aimed to study the outcome of emergency hospitalisation for ARLD by selecting a standardised starting point in the journey of individual patients. Hence, we focused on the first admission in any sequence of admissions and readmissions. We refer to these first admissions as index admissions. An index admission could be either a patient's first unplanned admission with ARLD in the dataset, or a readmission with a new acute decompensation after a long admission-free interval. Using the discharge date for each ARLD spell, we selected only those with no preceding discharge for ARLD in the prior 365 days.

Index admissions are a major milestone in the patient journey—representing a new, acute crisis for the individual patient. They represent a crucial point in the patient journey, an opportunity for co-ordinated intervention by the acute liver services and alcohol care team to reduce avoidable in-hospital morbidity and mortality, and set the patient on the path to long-term abstinence and recovery. By focusing on a standardised "first" admission, rather than pooling admissions and readmissions, there would be a better opportunity to make a fair comparison of outcomes of acute inpatient care between hospitals. Over the 4-year period, there were 2001 index admissions identified using primary diagnosis alone compared to 3887 admissions captured using the coding algorithm—an uplift of 1,886 index admissions with a coding sequence compatible with ARLD (Figure 1A).

2.7 | Primary outcome

The primary outcome was death during an index admission for ARLD. This was established from the discharge method variable in the dataset which records death in hospital.[20]

2.8 | Case mix variables

We extracted case mix variables for age, sex, co-morbidity and deprivation status of place of residence as previously described.[20] For co-morbidity we used Charlson co-morbidity Index as defined in the national Summary Hospital-level Mortality Index (SHMI), using the categorical version.[22] For category 1, the index is 0, category 2 has scores of 1-5 and category 3 is 6 and above. Deprivation status of place of residence was entered in our models using the Index of Multiple Deprivation Rank quintiles as defined at national level and we used quintile 5 (least deprived quintile) as the reference category as previously described.[20]

Recognising the variable presentations with specific complications of ARLD, we also created code lists for varices, ascites and acute kidney injury. We screened all ICD-10 codes in each episode of the index ARLD admissions and created binary variables for these clinical characteristics. Addition variables included whether the admission was a short stay (<2 days) and whether higher level or intensive care was required.

2.9 | Identification of outlier hospitals prior to the intervention

Our first objective was to determine whether there had been unexplained variation in risk-adjusted mortality between hospitals prior to launch of the AQ programme, thereby identifying any "outliers" for the baseline year (2014/2015). For the purpose of institutional comparison and creation of funnel plots, we generated a SMR for each fiscal year, representing the ratio of observed (O) to expected (E) deaths. The SMR is calculated by multiplying the standardised ratio (O/E) by 100. An SMR of 100 indicates that the observed number of deaths was equal to the expected number.

Expected deaths were determined using risk-adjustment procedures as described by Spiegelhalter.[23] Logistic regression models were constructed to estimate the probability of death at the end of each index admission within a fiscal year for each provider, thereby allowing expected deaths (E) to be calculated as the sum of those probabilities. To obtain these probabilities, we used stepwise binary logistic regression to determine adjusted odds of in-hospital death. Candidate independent variables included age group, sex, deprivation status, co-morbidity (Charlson score categories), ARLD-specific code recorded as primary diagnosis, disease-specific complications (varices, acute kidney injury, ascites), short stay status (<2 days) and requirement for higher level or intensive care.

By implementing stepwise selection of variables, we identified the combination of case mix variables that were significant predictors of in-hospital death. For this selection, we used conventional significance level thresholds for entering and removing case mix variables from logistic regression ($P < 0.05$ for entering and $P > 0.10$ for removing a variable) and used robust SEs to adjust for clustering of admission within patients. The case mix variables included in the overall logistic regression model after stepwise selection (in order of entry into the model based on statistical significance) were: Acute kidney injury ($P < 0.001$); Requirement for higher level or intensive care ($P < 0.001$); ARLD-specific code recorded as primary diagnosis ($P < 0.001$); Age group categories ($P < 0.001$); Charlson score categories ($P < 0.001$); Ascites ($P = 0.001$); Short stay status (<2 days) ($P = 0.002$); Varices ($P = 0.024$). We compared performance of basic adjustment models (containing only generic case

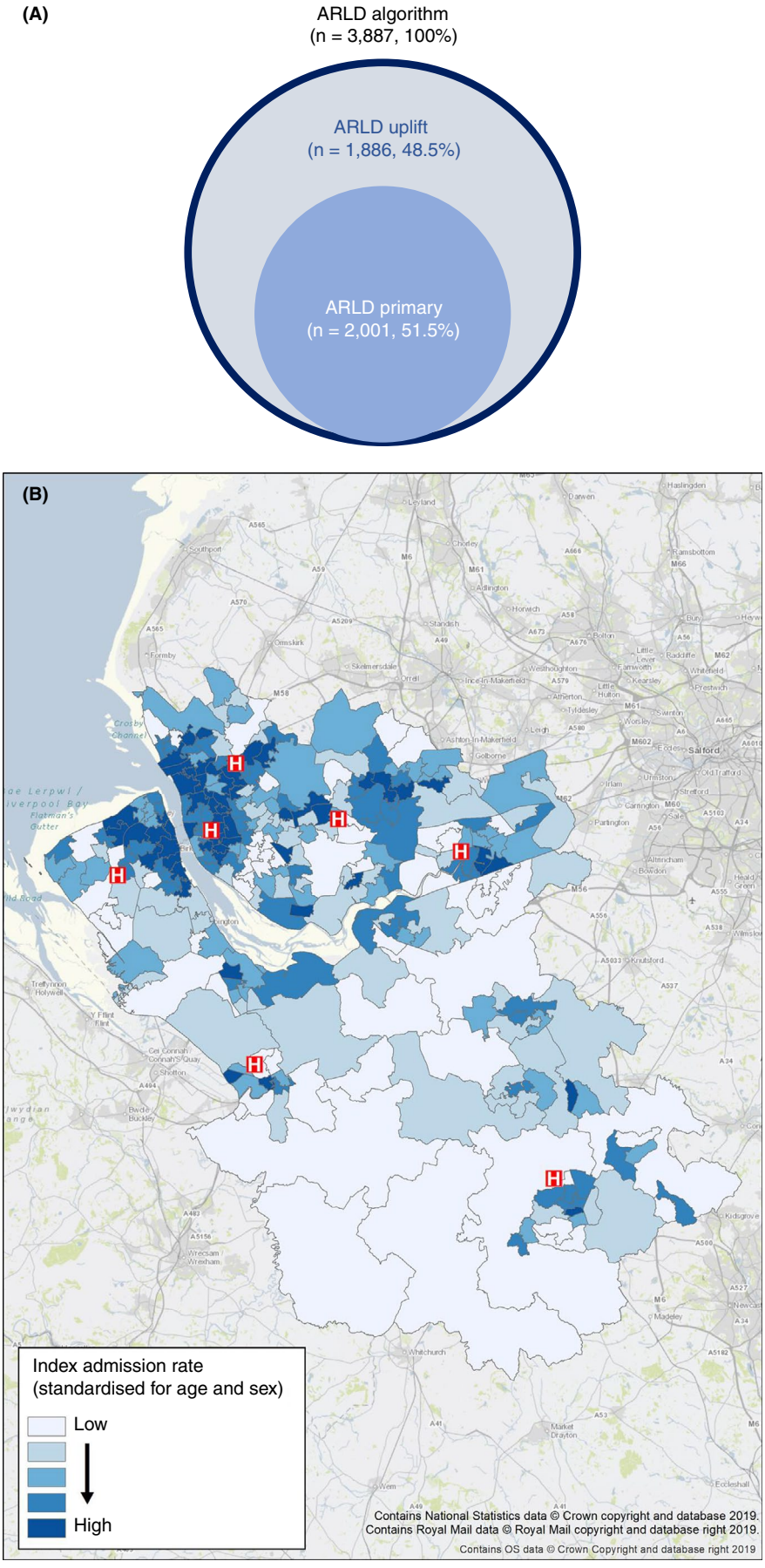

FIGURE 1 (a) Comparison of traditional method (ARLD-Primary) and clinically designed algorithm (ARLD-Algorithm) for cohort discovery of index admissions for alcohol-related liver disease (ARLD) from routine administrative data (pooled data for seven hospitals for the period 2014/2015 to 2017/2018). The algorithmic approach identifies an "uplift" of 48% (ie potentially missed cases) with coding patterns compatible with an admission for symptoms, signs and/or complications of ARLD. See Table 1 for overview of diagnostic coding rules, and Tables S1–S4 for code lists. (b) Geographical distribution of ARLD-Algorithm index admissions and location of seven hospitals included in the study. Shaded areas represent Middle Layer Super Output Areas of residence (mean population of 7200 residents per area). Colours represent quintiles of age- and sex-standardised rate of ARLD-algorithm admissions per capita using pooled data for the entire 4-y period

mix factors) to more advanced models (using alternative sets of variables) by examining the proportion of variation in mortality explained (pseudo-R^2 statistic), and then adopted the optimum model for risk-adjustment.

For creating funnel plots, we used the *funnelcompar* command in STATA statistical package version 15 (which is based on Spiegelhalter),[23] we identified whether SMR relative to the number of index admissions[24] was within acceptable limits (i.e. within 2 SD; 95%), between 2 and 3 SD, or beyond 3 SD (99.8%). An outlier in 2014/2015 (baseline year) was defined as a provider where SMR was beyond the upper 3 SD control limit.

2.10 | Comparison of risk-adjusted mortality for the pre- and post-intervention periods

We generated a series of funnel plots, one for each fiscal year, to illustrate time trends in the degree of inter-institutional variation, as previously described.[25] Having identified a group of outlier hospitals with "higher than expected" mortality prior to the intervention, we applied a categorical variable to represent all admissions to those hospitals throughout the observation period. This allowed risk-adjusted mortality models to examine time trends in mortality risk separately for outlier hospitals (where unexplained mortality had been identified) and non-outlier hospitals (where no such signals were present at baseline).

To test the significance of time trends in adjusted odds of death, we used fiscal year of admission as a categorical variable and designated the pre-intervention year (2014/2015) as the comparator. We also explored any individual hospital "effects," by adding a categorical variable to represent admission to each of the seven hospitals. This allowed us to test any specific associations for individual providers beyond their baseline grouping as outlier or non-outlier hospitals.

2.11 | Analysis of local audit data at the beginning and end of the observation period

We compared the locally collected audit data for performance on AQ process measures, pooling data for those hospitals identified as outliers and non-outliers for inpatient mortality for 2014/2015. We implemented binomial regression to compare for each clinical indicator the proportion of successful implementations during the 3 month baseline period and the final comparable time period (January 2018-March 2018).

3 | RESULTS

3.1 | Demographic and clinical characteristics

Over the 4 fiscal years, there were 3887 index emergency admissions for ARLD to the seven hospitals (Table 2). The geographical distribution of the admissions and location of hospitals is shown in Figure 1B. The mean age at the time of index admission was 53 years, with men accounting for 63%. Over half (56.8%) were residents of an area classified within the most deprived quintile for the country, 15.5% were in quintile 2, 11.2% in quintile 3, 9.4% in quintile 4 and just 7.1% in quintile 5 (least deprived).

Overall, approximately one in five patients had ICD-10 codes consistent with acute kidney injury (21.7%), one in three had codes compatible with ascites (32.4%) and over one in six patients had varices (15.5%). The median length of stay was 6 days (IQR: 3-14). Short stays (<2 days) accounted for 14.1% of index admissions. There were 304 admissions that required a period of higher level or intensive care (7.8%), indicating severe disease complications.

3.2 | Deaths in hospital and case mix factors associated with in-hospital death

There were 534 in-hospital deaths during index admissions (crude mortality rate of 13.7%). Compared to those discharged alive, patients who died during their index admission were older (mean age 57.7 vs 52.8, $P < 0.001$), more frequently female (41.2% vs 36.3%, $P = 0.030$) and had more co-morbidities (72.5% vs 48.4% with Charlson index >5, $P < 0.001$), acute kidney injury codes (66.5% vs 14.5%, $P < 0.001$), ascites codes (53.6% vs 29.0%, $P < 0.001$) and requirement for intensive or higher level care (31.1% vs 4.1%, $P < 0.001$). The average deprivation status (mean IMD Rank) of those who died was actually somewhat higher (ie more affluent) than survivors (9529 vs 8572, $P = 0.024$). The proportion of patients with codes for varices was greater but not significantly different among those who died (16.9% vs 15.3%, $P = 0.357$).

3.3 | Variation in mortality between hospitals prior to the AQ programme and identification of outliers

We compared performance for risk-adjusted mortality (SMR) using funnel charts, plotting mortality vs number of index admissions. In the fiscal year prior to roll-out of the AQ programme (2014/2015), three hospitals had an SMR above the upper 3SD control limit (Figure 2A)—suggesting special cause or unwarranted variation. Using stepwise logistic regression analysis, we further confirmed that patients admitted to the outlier group of hospitals had an increased adjusted odds of death (OR 2.13, 95% CI 1.32-3.44, $P = 0.002$) compared to those admitted to the non-outlier hospitals during that year (Table 3a).

3.4 | Time trends in variation between hospitals and elimination of outliers

Over the observation period there was a step-wise reduction in the number of hospitals with an SMR lying outside the upper 3 SD funnel

TABLE 2 Characteristics and outcome of index admissions for alcohol-related liver disease (ARLD) to seven acute NHS hospitals in the North West region of England. Stratified by fiscal year and survival status

Characteristic[a]	2014/2015	2015/2016	2016/2017	2017/2018	Total	Survived	Died
Index admissions	957	1022	953	955	3887	3353	534
Male	585	663	593	609	2450	2136	314
	61.1%	64.9%	62.2%	63.8%	63.0%	63.7%	58.8%
Age (mean)	52.3	53.4	54.0	54.1	53.4	52.7	57.7
(SD)	11.9	11.5	12.2	11.6	11.8	11.7	11.7
Deprivation (mean IMD rank)	8038	8811	8997	8963	8704	8572	9529
Most deprived quintile	575	582	522	530	2209	1933	276
	60.1%	56.9%	54.8%	55.5%	56.8%	57.6%	51.7%
ARLD code in primary[b]	480	550	508	463	2001	1636	365
	50.2%	53.8%	53.3%	48.5%	51.5%	48.8%	68.4%
Short stay (<2 d)	136	150	117	147	550	492	58
	14.2%	14.7%	12.3%	15.4%	14.1%	14.7%	10.9%
HDU and/or ITU	80	68	72	84	304	138	166
	8.4%	6.7%	7.6%	8.8%	7.8%	4.1%	31.1%
Charlson Index, Score 0	374	401	313	309	1397	1299	98
	39.1%	39.2%	32.8%	32.4%	35.9%	38.7%	18.4%
Charlson Index, Score 1-5	124	140	105	112	481	432	49
	13.0%	13.7%	11.0%	11.7%	12.4%	12.9%	9.2%
Charlson Index, Score >5	459	481	535	534	2009	1622	387
	48.0%	47.1%	56.1%	55.9%	51.7%	48.4%	72.5%
Acute kidney injury codes	161	191	244	246	842	487	355
	16.8%	18.7%	25.6%	25.8%	21.7%	14.5%	66.5%
Ascites codes	298	308	333	320	1259	973	286
	31.1%	30.1%	34.9%	33.5%	32.4%	29.0%	53.6%
Varices codes	162	146	139	156	603	513	90
	16.9%	14.3%	14.6%	16.3%	15.5%	15.3%	16.9%
Died	123	124	152	135	534	0	534
	12.9%	12.1%	15.9%	14.1%	13.7%	0.0	100%

[a]Counts and percentages unless otherwise stated.

[b]Specific ICD-10 codes for ARLD recorded as the primary diagnosis.

limit in each successive fiscal year (Figure 2A-D). By 2017/2018, there were no outliers. Figure 3 shows adjusted mortality data for the individual hospitals, comparing SMR in 2014/2015 with 2017/2018.

As expected from these observations, the magnitude of variation in SMR between the hospitals reduced significantly over the 4 years, with a standard deviation of 26, 28, 19 and 12 respectively. Taken together, these data provide evidence for a reduction in unexplained or potentially "avoidable" mortality and a narrowing of variation between hospitals.

3.5 | Associations between admission year and odds of death according to outlier status

We further examined time trends in a series of models. Taking the pre-intervention year as the reference year (2014/2015), there was a significant association between fiscal year of admission and a reducing odds of death for patients admitted to the three outlier hospitals (Table 4a). Admission in 2017/2018 was associated with a 67% reduction in adjusted odds of death compared to the pre-intervention year (OR 0.33, 95% CI 0.18-0.63, P = 0.001). Hence, for hospitals identified as having a high SMR prior to the AQ intervention, the risk of death was significantly reduced over time. This suggests a reduction in "avoidable" mortality.

There was no significant association between fiscal year of admission and odds of death for patients admitted to the hospitals that were not mortality outliers in the pre-intervention year (Table 4b). Hence, risk-adjusted mortality during index admissions was unchanged over time. This would be expected, as non-outlier hospitals were not identified as having "special cause" variation in mortality prior to the QI programme and so would have less

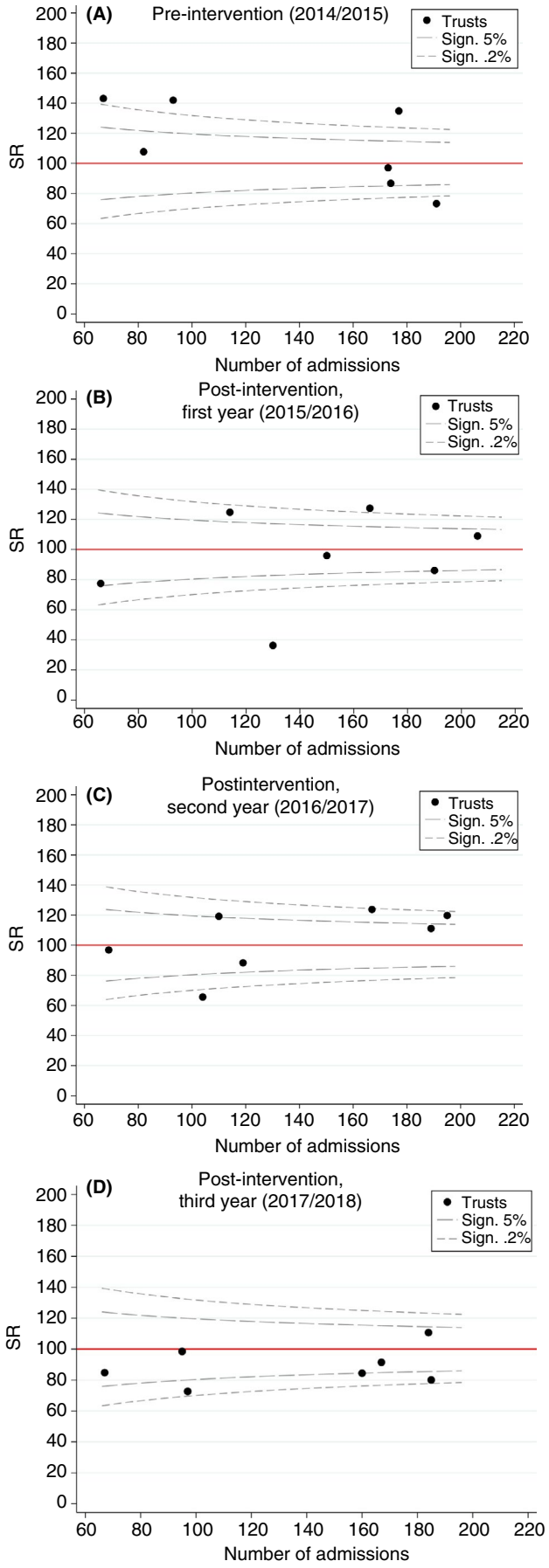

FIGURE 2 Reduction in unexplained variation in mortality for index admissions for alcohol-related liver disease (ARLD) between 2014/2015 and 2017/2018 for seven hospitals in the North West region of England that participated in a QI programme. Funnel plots of standardised mortality ratio (SMR) for ARLD for the pre-intervention year (2014/2015) and 3 consecutive years after the start of the Advancing Quality programme. In the pre-intervention year (A), three of seven hospitals were identified retrospectively as having been "outliers" for mortality (standardised mortality ratio [SMR] above the upper 98% control limit). There was a stepwise reduction in the number of outliers over time, with none persisting by the final year (D). Dotted lines represent the 95% (5% significance) and 98% (2% significance) control limits. SMR is plotted against number of index admissions. (A) Pre-intervention (2014/2015). (B) Post-intervention, first year (2015/2016). (C) Post-intervention, second year (2016/2017). (D) Post-intervention, third year (2017/2018)

potential for measurable improvement. This suggests performance was maintained, but neither improved nor deteriorated significantly.

To confirm that the "year effect" was specific to the outlier hospitals, we implemented a logistic regression model with all seven hospitals with the addition of an interaction term between outlier status indicator and year indicators (Table 4c). No association was apparent for non-outliers, but there was a significant difference for the outlier group.

Finally, in a model containing data for all hospitals for 2017/18 (Table 3b), there was no significant association between adjusted odds of death and being admitted to one of the original outlier hospitals (OR 0.72, 95% CI 0.46-1.15, $P = 0.171$), in contrast to the findings for the pre-intervention year (Table 3a).

3.6 | Comparison of locally collected audit data at outlier and non-outlier group of hospitals

Modifications to the number and definitions of process measures over the course of the AQ initiative precluded a robust analysis of serial trends for individual measures. However, at the time of initiation of the programme, as a group the outlier hospitals had significantly lower performance than the non-outlier group in 5 of an original set of 11 process measures (46%), Table 5a. By the end of the observation period, there was significantly lower performance in only two of seven revised process measures (29%), Table 5b. These data suggest that care processes at outlier hospitals had greater scope for improvement at the start of the programme than at the non-outlier group. Furthermore, performance differences between the two groups of hospitals reduced over time.

The financial incentive scheme (annual CQIN payment linked to participation) was taken up by the commissioners of two non-outlier and one outlier hospital, suggesting that this financial incentive *per se* was not associated with the successful implementation.

TABLE 3 Association between admission to an original outlier hospital and case mix adjusted odds of inpatient death in 2014/2015 (pre-intervention) and 2017/2018 (post-intervention). (a) In 2014/2015, admission to an "outlier" hospital was confirmed to be independently associated with an increased odds of inpatient death for alcohol-related liver disease; (b) By 2017/2018, admission to one of the original outlier hospitals was no longer associated with an increased odds of death

Variable[a]	Adjusted odds ratio (OR)	95% CI	*P*-value
(a) Pre-intervention year (2014/2015)			
Admitted to outlier hospital[b]	2.13	1.32-3.44	0.002
Acute Kidney Injury codes	10.33	6.37-16.77	<0.001
HDU and/or ITU	9.55	5.12-17.79	<0.001
ARLD code in primary	4.16	2.46-7.05	<0.001
Age group (y)			
18-39 (reference group)	Ref.	Ref.	Ref.
40-49	1.23	0.43-3.56	0.697
50-59	3.02	1.10-8.27	0.032
60-69	3.69	1.33-10.24	0.012
70 and above	3.95	1.24-12.55	0.020
(b) Post-intervention year (2017/2018)			
Admitted to outlier hospital[b]	0.72	0.46-1.15	0.171
Acute Kidney Injury codes	8.89	5.70-13.88	<0.001
HDU and/or ITU	3.91	2.25-6.80	<0.001
Ascites	1.81	1.17-2.80	0.007
Charlson index category			
0 (reference group)	Ref.	Ref.	Ref.
1-5	1.54	0.66-3.61	0.319
>5	2.31	1.32-4.05	0.004

[a]Only retained variables in stepwise logistic regression models are shown. See text for full list of variables.

[b]Outlier status was determined by identifying hospitals with a standardised mortality ratio (SMR) lying above the 3 SD upper control limit in the pre-intervention year (2014/2015), as shown in funnel plot (Figure 2A). Three hospitals were outliers.

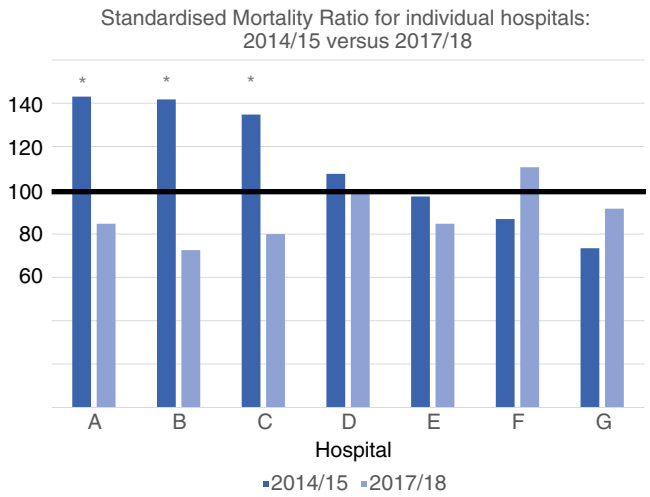

FIGURE 3 Comparison of case mix adjusted mortality for index admissions for alcohol-related liver disease (ARLD) to each of seven hospitals in 2014/2015 (pre-intervention) and 2017/2018 (post-intervention). Bars indicate standardised mortality ratios (SMRs). Asterisk identifies the three hospitals with an SMR above the three SD control limit in 2014/2015, designated "outliers"

3.7 | Performance of outliers and non-outliers on publicly available all-cause mortality statistics

We compared our findings for ARLD-specific mortality with publicly available statistics for all-cause hospital mortality for 2014/2015, based on the SHMI indicator.[22] Only one of the three outlier hospitals for ARLD mortality from our models had a SHMI above the national upper limit and none of the non-outlier hospitals. Hence, our "outlier" hospitals for ARLD mortality in the pre-intervention year were not identifiable as a group of providers that had a general pattern of unexplained all-cause mortality in routinely published statistics. This suggests our findings are relevant to acute care for ARLD rather than reflective of more generic institutional factors.

4 | DISCUSSION

To our knowledge this is the first study to demonstrate a reduction in unexplained variation in hospital mortality for ARLD associated

TABLE 4 Association between fiscal year of admission and case mix adjusted odds of inpatient death for the outlier group and non-outlier group of hospitals. (a) Compared to the pre-intervention year, adjusted odds of death for index admissions for alcohol-related liver disease (ARLD) was significantly reduced in post-intervention years 2015/2016 and 2017/2018 at outlier hospitals. (b) There was no significant association between year of admission and adjusted mortality at non-outliers. (c) A model containing all seven hospitals confirmed that a significant "year effect" was only apparent at the original outlier group of hospitals

Financial year of admission	Adjusted odds ratio[a] (OR)	95% CI	*P*-value
(a) Model for outlier group (n = 3 hospitals)			
2014/2015 (pre-intervention)	Ref.	Ref.	Ref.
2015/2016 (post-intervention)	0.41	0.23-0.73	0.002
2016/2017 (post-intervention)	0.69	0.42-1.13	0.143
2017/2018 (post-intervention)	0.33	0.18-0.63	0.001
(b) Model for non-outlier group (n = 4 hospitals)			
2014/2015 (pre-intervention)	Ref.	Ref.	Ref.
2015/2016 (post-intervention)	1.35	0.89-2.03	0.157
2016/2017 (post-intervention)	1.22	0.80-1.84	0.360
2017/2018 (post-intervention)	1.19	0.79-1.80	0.399
(c) Model containing outlier and non-outlier group (n = 7 hospitals)			
Year effects (non-outlier groups)			
2014/2015 (pre-intervention)	Ref.	Ref.	Ref.
2015/2016 (post-intervention)	1.37	0.90-2.10	0.140
2016/2017 (post-intervention)	1.21	0.79-1.86	0.376
2017/2018 (post-intervention)	1.19	0.78-1.82	0.420
Outlier group (ref. non-outlier)			
2014/2015 (pre-intervention)	2.19	1.37-3.49	0.001
2015/2016 (post-intervention)	0.30	0.16-0.59	<0.001
2016/2017 (post-intervention)	0.60	0.32-1.11	0.103
2017/2018 (post-intervention)	0.31	0.16-0.63	0.001

[a]Logistic regression models include age group, sex, Charlson co-morbidity index, deprivation status, ARLD coded as primary diagnosis, short stay, high dependency unit (HDU) and/or intensive therapy unit (ITU) care, codes for acute kidney injury, ascites and varices.

[b]This model includes an interaction between outlier status and year.

with a QI programme. We began by determining whether there had been "unexplained" variation in mortality between hospitals prior to the intervention, confirming a number of outliers. As a group, the outlier hospitals had significantly poorer performance on 5 of 11 AQ measures (46%) at the start of the programme. Our analyses of independent administrative data showed that the adjusted odds of death for index cases admitted to "outlier" hospitals was significantly higher in the year before the AQ intervention (twofold). We were able to show that institutional performance improved over time, as reflected by elimination of mortality outliers following roll-out of the QI programme. The adjusted odds of death in post-intervention years was reduced compared to the pre-intervention year at outlier hospitals, but it remained unchanged for the other hospitals. Although the number and definitions of local AQ measures evolved over the course of the programme, the original outlier group had lower performance in only two of seven care process metrics (29%) by the end of the observation period.

Variation in acute care quality for cirrhosis has been highlighted in other countries with proposals on a wide range of metrics to support QI,[10,7,11,8,12] but there has been frustratingly little evidence published to show whether reductions in avoidable hospital mortality can be achieved.[14] The original panel of measures in the North West AQ programme contained elements of the recently endorsed "liver bundle",[26,27] and formal completion of a local bundle proforma was one of the AQ measures. Rates of completion of bundle documentation at our hospitals were relatively low, compared with metrics of specific processes. Further research is needed to identify the optimum bundle of interventions, quality metrics and implementation models needed to achieve sustained, service-wide reductions in avoidable inpatient deaths during the acute phase of care.

Our study has a number of strengths. Rather than focusing on data captured for samples of cases included in periodic local audits, we used administrative data as it is independent of the audit process and allows unbiased case ascertainment over a continuous observation period. By including a sample of hospitals with significant variation in baseline performance for mortality, our evaluation was able to explore trends for hospitals with, and without, outlying performance.

We applied clinically informed methods for interrogating administrative data. Lack of credibility for simplistic analyses of discharge coding among front-line teams has led to calls for better approaches to using administrative data to capture hospital activity for alcohol-related conditions.[28] We confirmed that for ARLD it was necessary to improve on the traditional "primary diagnosis" approach for cohort identification, developing a novel clinically designed algorithm to reflect the complexity of clinical presentations and real-world coding practice.

Although modest in scale, our validation against local hospital records showed clear evidence for incomplete case identification with the traditional approach (sensitivity just 61.5%) and the merits of an algorithmic approach. Routine statistics based on primary

TABLE 5 Local audit data for the Advancing Quality (AQ) process metrics[a], comparing pooled data for the "outlier" and "non-outlier" group of hospitals. Significant differences in performance between the two groups on individual metrics are highlighted in bold text

Measure	Description	Non-outliers (%)	Outliers (%)	*P*-value
(a) Original set of 11 quality measures at the start of the programme (2015/2016)				
ARLD-01	Early warning score recorded within 60 min of hospital arrival[a]	86.2	74.5	0.143
ARLD-02	**Alcohol misuse screening within 4 h of hospital arrival[b]**	**89.3**	**72.2**	**0.002**
ARLD-03	**Antibiotics and Terlipressin within 4 h of suspected variceal bleed**	**77.8**	**17.9**	**<0.001**
ARLD-04	**IV Pabrinex[c] within 6 h of hospital arrival**	**54.5**	**36.0**	**<0.001**
ARLD-05	Blood tests results available within 4 h of hospital arrival	90.7	89.6	0.162
ARLD-06	**Ascitic tap performed within 8 h of hospital arrival**	**52.3**	**35.8**	**0.047**
ARLD-07	Gastroenterology or Hepatology ward admission or specialist review within 48 h of hospital arrival	70.8	71.4	0.701
ARLD-08	Patient seen by or referred to alcohol services prior to discharge[b]	77.1	53.2	0.072
ARLD-09	Risk of alcohol withdrawal assessed within 4 h of hospital arrival[d]	44.7	22.3	0.143
ARLD-10	Care bundle commenced within 4 h of hospital arrival[e]	28.5	20.1	0.704
ARLD-11	**Serum lactate taken within 3 h of hospital arrival[f]**	**28.0**	**10.4**	**0.045**
b. Revised Set of Seven Quality Measures (2017/2018)				
ARLD-12	Alcohol screen and referral to Alcohol Care Team within 24 h of hospital arrival[b]	74.8	72.2	0.568
ARLD-13	Risk of alcohol withdrawal assessed within 4 h of hospital arrival[d]	52.6	20.6	0.054
ARLD-14	Antibiotics and terlipressin within 4 h of senior review documentation of suspected variceal bleed	78.6	83.3	1.000
ARLD-15	IV Pabrinex within 6 h of hospital arrival[c]	57.5	56.4	0.545
ARLD-16	**Ascitic tap performed within 8 h of senior review documentation to tap**	**96.4**	**33.3**	**0.001**
ARLD-17	Gastroenterology or Hepatology ward admission or specialist review within 48 h of hospital arrival	88.8	69.4	0.180
ARLD-18	**Care bundle utilised during patient hospital stay[e]**	**27.2**	**0.0**	**<0.001**

Note: Further details of the AQ metrics are available on request: advancing.quality@nhs.net

[a]ARLD-01 (baseline nursing observations used to calculate the local "Early Warning Score") was retired in the revised set as performance for this generic process measure was consistently high at all hospitals.

[b]ARLD-02 and -08 were merged into one measure, ARLD-12, in the revised set. "Screening" refers to documentation of answers to at least one of three screening questions for alcohol excess.

[c]Pabrinex = Intravenous High Potency, Concentrate for Solution for Infusion (Vitamin B1) (Kyowa Kirin Ltd).

[d]Risk of alcohol withdrawal required the documentation of a validated risk score (eg the AUDIT-C or CAGE screening tools).

[e]"Care bundle" was any locally approved decision-support document that outlined the AQ measures and was completed for the individual patient and available in the case records.

[f]ARLD-11 was retired as it was considered more relevant to sepsis pathways than ARLD per se.

diagnosis alone may miss almost 40% of true admissions for ARLD, seriously under-estimating burden and risking the generation of misleading metrics. We focused specifically on index admissions to identify a fixed point in the care pathway and establish a more level playing field for institutional comparisons.

Further evidence for face validity of our cohort identification method is provided by comparing the characteristics of patients who died to that of the national sample of inpatient deaths reviewed by NCEPOD.[4] In that report, 20% of ARLD deaths occurred within 72 hours of admission (vs 22% in our study), mean age was 58 years (as in our study), gastrointestinal bleeding in 20.7% (vs 17% with varices codes) and ascites in 55.7% (vs 54% with relevant codes). The NCEPOD review only reported "established renal failure at presentation," but this was highly prevalent at 30% for those dying during admission (vs 66% with codes for acute kidney injury among deaths in our study). A recent study of people who died from liver disease in England identified renal complications as strongly associated with hospital death.[29]

We focused deliberately on in-hospital mortality during index admissions as we believe this metric was of most relevance to the potential impact of the QI programme. The AQ measures were targeting the essential elements of acute hospital care in the early days of an emergency admission. We did not study post-discharge or longer term mortality, as these outcomes would be influenced by subsequent ambulatory hospital aftercare (eg liver clinics) and community-based alcohol services.

Our analysis of in-hospital mortality moved beyond simple generic risk-adjustment variables (age, gender, co-morbidity index, deprivation status) to include condition-specific case mix factors associated with liver disease severity and complications. Sensitivity analyses explored models with alternative sets of variables to illustrate which factors were independently associated with mortality and to optimise final models. Compared to a simple, generic approach (pseudo-R^2 was just 5.5%), the proportion of mortality variation explained by the final model was sixfold greater (pseudo-R^2, 30.7%). This suggests our condition-specific case mix factors were relevant surrogates for patient factors associated with death.

We propose that our methodology for analysing inpatient mortality for index ARLD admissions from administrative data could be adopted nationally, helping to identify potentially unexplained variation in outcomes of care at a key point in the care pathway. This would support targeted reviews of service provision, organisation and care process—complimenting recent efforts to encourage formal accreditation of units under the Improving Quality in Liver Services (IQILS) programme.[30] By focusing on deaths during index admissions we have concentrated on acute secondary care for first admissions for ARLD, rather than the common approach of pooling together both admissions and remissions to generate "admission-level" mortality metrics that can be difficult to interpret.

This evaluation has a number of limitations. We cannot determine cause and effect from an uncontrolled observational study, and the temporal trends observed could have been driven by factors external to the QI programme. However, this does not negate the evidence presented for a narrowing of inter-institutional variation and a selective reduction in mortality risk at those hospitals that began the period as "outliers." This is good news for patients, regardless of precise mechanism. Our data suggest that it is, indeed, possible for hospitals to achieve reductions in potentially avoidable mortality for ARLD. The reasons for this improvement will be complex and multifactorial, but we believe it is reasonable to infer an impact of the QI programme.

General secular trends in population characteristics or health service improvements would not be expected to operate selectively at the three "outlier" hospitals and create no signals at the others. Our review of publicly available metrics of hospital mortality revealed just one of the seven hospitals had "higher than expected" all-cause inpatient mortality in 2014/2015 (only one of the three "outliers" for ARLD mortality). This suggests our observations are condition specific rather than mirroring general trends of mortality at these hospitals.

There are well-known limitations to discharge coding data, including potential variations or inaccuracies and a lack of granular clinical information for case mix or laboratory data to allow true assessment of disease severity. However, the aim of our work was to develop better ways to use currently available administrative datasets to study outcomes of hospital care. It is hoped that future progress with structured electronic health records will enhance the opportunities for continuous monitoring of risk-adjusted outcomes at regional or national scales, with access to richer clinical variables such as laboratory parameters of liver disease severity. However, for the time being we propose our methods could be applied to national administrative datasets to identify variation and support nationwide programmes focused on improving acute hospital care for ARLD. We have not attempted to compare characteristics of individual hospital services or to draw inferences about local factors associated with "outlier" status. Our aim was to establish that variation in mortality between providers was present before the QI programme started and that it reduced afterwards.

5 | CONCLUSIONS

This study challenges the pessimism and therapeutic nihilism that is prevalent for this vulnerable group of "hard-to-help" patients.[31] Lack of progress in policies for prevention has been highlighted recently,[32] emphasising the ongoing need to optimise acute services to deal with the ongoing demands for emergency liver and alcohol care. Notwithstanding the well-known limitations of an uncontrolled observational study, these data provide hope that co-ordinated efforts to drive adoption of evidence-based practice for acute care of ARLD can save lives. Further research is needed to identify the optimum bundle of interventions, quality metrics and implementation models needed to achieve sustained, service-wide reductions in avoidable inpatient deaths in the acute phase of care.

ACKNOWLEDGEMENTS

In addition to the authors (P.R., S.R and S.H.), the Clinical Expert Group for the AQ ARLD Collaborative from participating hospitals included: Dr Lynne Owens (Royal Liverpool University Hospital), Dr Julie Dobson (St Helens and Knowsley Hospitals NHS Trust), Dr Saravanan Ramasamy (East Cheshire NHS Trust) and Dr Venkata Lekharaju (Wirral University Teaching Hospital NHS Trust). The AQuA team included Liz Kanwar (AQ Programme Manager), Claire Geoghegan (ARLD Focus Area Lead) and Stephen Messenger (Associate). We thank all the hospital teams who contributed to the AQ programme.

Declaration of personal interests: K.B. has received educational support from Boston Scientific, Takeda and Janssen. S.R. received speaker fees from Mylan. C.K., P.D., M.S., B.S., L.A., and R.G. have no interests to declare.

AUTHORSHIP

Guarantor of the article: K.B.

Author contributions: K.B. wrote the manuscript and all authors reviewed and approved the final submission. K.B., C.K., P.D., B.S. and S.H. designed the research with input from other authors. C.K. and P.D. curated and analysed the data, supervised by K.B., with input from M.S., B.S. and R.G. The AQ Clinical Expert Group included P.R., S.R. and S.H. All authors contributed to review of the manuscript.

ORCID

Keith Bodger https://orcid.org/0000-0002-1825-3239

REFERENCES

1. Burton R, Sheron N. Missed opportunities for intervention in alcohol-related liver disease in the UK. *Lancet Gastroenterol Hepatol*. 2017;2:469–471.
2. Williams R, Aspinall R, Bellis M, et al. Addressing liver disease in the UK: a blueprint for attaining excellence in health care and reducing premature mortality from lifestyle issues of excess consumption of alcohol, obesity, and viral hepatitis. *Lancet Lond Engl*. 2014;384:1953–1997.
3. McPherson S, Lucey MR, Moriarty KJ. Decompensated alcohol related liver disease: acute management. *BMJ*. 2016;352:i124.
4. National confidential enquiry into patient outcome and death. Measuring the units: a review of patients who died with alcohol-related liver disease [Internet], 2013. https://www.ncepod.org.uk/2013report1/downloads/MeasuringTheUnits_FullReport.pdf (accessed October 1, 2019).
5. Government urged to take action to tackle liver disease – telegraph [Internet]. https://www.telegraph.co.uk/news/health/10723114/Government-urged-to-take-action-to-tackle-liver-disease.html (accessed September 30, 2019).
6. Williams R, Alexander G, Aspinall R, et al. Gathering momentum for the way ahead: fifth report of the Lancet Standing Commission on Liver Disease in the UK. *Lancet Lond Engl*. 2018;392:2398–2412.
7. Kanwal F, Kramer JR, Buchanan P, et al. The quality of care provided to patients with cirrhosis and ascites in the Department of Veterans Affairs. *Gastroenterology*. 2012;143:70–77.
8. Ghaoui R, Friderici J, Visintainer P, Lindenauer PK, Lagu T, Desilets D. Measurement of the quality of care of patients admitted with decompensated cirrhosis. *Liver Int*. 2014;34:204–210.
9. Kanwal F, Kramer J, Asch SM, et al. An explicit quality indicator set for measurement of quality of care in patients with cirrhosis. *Clin Gastroenterol Hepatol*. 2010;8:709–717.
10. Bassett JT, Volk ML. Can quality of care for patients with cirrhosis be measured? *Dig Dis Sci*. 2011;56:3488–3491.
11. Kanwal F, Volk M, Singal A, Angeli P, Talwalkar J. Improving quality of health care for patients with cirrhosis. *Gastroenterology*. 2014;147:1204–1207.
12. Le S, Spelman T, Chong C-P, et al. Could adherence to quality of care indicators for hospitalized patients with cirrhosis-related ascites improve clinical outcomes? *Am J Gastroenterol*. 2016;111:87–92.
13. Dyson JK, Rajasekhar P, Wetten A, et al. Implementation of a "care bundle" improves the management of patients admitted to hospital with decompensated cirrhosis. *Aliment Pharmacol Ther*. 2016;44:1030–1038.
14. Bosch J. Editorial: improving in-hospital management of decompensated cirrhosis by a "care bundle" - hope, frustration, and lessons to learn. *Aliment Pharmacol Ther*. 2017;45:754–755.
15. Public Health Profiles [Internet]. https://fingertips.phe.org.uk/profile/local-alcohol-profiles/data#page/3/gid/1938132984/pat/6/par/E12000002/ati/101/are/E08000012/iid/91380/age/1/sex/4 (accessed October 12, 2019).
16. Using data and technology to improve services for alcohol related illness [Internet]. Connected Health Cities. https://www.connectedhealthcities.org/research-projects/development-learning-system-alcohol/ (accessed October 12, 2019).
17. Advancing Quality Alliance - improving the quality of health and care [Internet]. https://www.aquanw.nhs.uk/ (accessed September 30, 2019).
18. Sutton M, Nikolova S, Boaden R, Lester H, McDonald R, Roland M. Reduced mortality with hospital pay for performance in England. *N Engl J Med*. 2012;367:1821–1828.
19. Advancing quality – alcohol related liver disease [Internet]. https://www.aquanw.nhs.uk/events/advancing-quality-alcohol-related-liver-disease/80206 (accessed September 30, 2019).
20. Shawihdi M, Thompson E, Kapoor N, et al. Variation in gastroscopy rate in English general practice and outcome for oesophagogastric cancer: retrospective analysis of hospital episode statistics. *Gut*. 2014;63:250–261.
21. Pang JXQ, Ross E, Borman MA, et al. Validation of coding algorithms for the identification of patients hospitalized for alcoholic hepatitis using administrative data. *BMC Gastroenterol*. 2015;15:116.
22. Clinical Indicators Team (NHS Digital). Indicator specification: Summary Hospital-level Mortality Indicator (SHMI) [Internet]. Health & Social Care Information Centre; 2018, p. 38. https://files.digital.nhs.uk/7C/3D29F3/SHMI%20specification.pdf (accessed January 1, 2017).
23. Spiegelhalter DJ. Funnel plots for comparing institutional performance. *Stat Med*. 2005;24:1185–1202.
24. Verburg IW, Holman R, Peek N, Abu-Hanna A, de Keizer NF. Guidelines on constructing funnel plots for quality indicators: a case study on mortality in intensive care unit patients. *Stat Methods Med Res*. 2018;27:3350–3366.
25. Shawihdi M, Dodd S, Kallis C, et al. Nationwide improvement in outcomes of emergency admission for ulcerative colitis in England, 2005–2013. *Aliment Pharmacol Ther*. 2019;50:176–192.
26. McPherson S, Dyson J, Austin A, Hudson M. Response to the NCEPOD report: development of a care bundle for patients admitted with decompensated cirrhosis-the first 24 h. *Frontline Gastroenterol*. 2016;7:16–23.
27. BSG – BASL decompensated cirrhosis care bundle – First 24 Hours [Internet]. https://www.bsg.org.uk/resource/bsg-basl-decompensated-cirrhosis-care-bundle.html (accessed September 30, 2019).
28. Moriarty KJ. Alcohol-related disease: meeting the challenge of improved quality of care and better use of resources [Internet]. British Society of Gastroenterology. 2010; https://www.bsg.org.uk/asset/18EA068C-502F-42CF-A39590845D42C6D3/

29. Peng J-K, Higginson IJ, Gao W. Place of death and factors associated with hospital death in patients who have died from liver disease in England: a national population-based study. *Lancet Gastroenterol Hepatol*. 2019;4:52–62.
30. IQILS [Internet]. https://www.iqils.org/CMS/Page.aspx?PageId=80 (accessed October 19, 2019).
31. Mitchison H, Saksena S, Hudson M. NCEPOD and alcohol-related liver disease, what are the views of those who deliver the service? A survey of consultants and trainees in North Eastern England. *J R Coll Physicians Edinb*. 2018;48:293–298.
32. Williams R, Aithal G, Alexander GJ, et al. Unacceptable failures: the final report of the Lancet Commission into liver disease in the UK. *Lancet Lond Engl*. 2020;18:226–239.

SUPPORTING INFORMATION

Additional supporting information will be found online in the Supporting Information section.

How to cite this article: Kallis C, Dixon P, Silberberg B, et al. Reducing variation in hospital mortality for alcohol-related liver disease in North West England. *Aliment Pharmacol Ther*. 2020;00:1–14. https://doi.org/10.1111/apt.15781