Is there seasonal variation in gallstone related admissions in England?

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Declarations of interest: Dr Killick gratefully acknowledges funding from EPSRC under grant EP/T014105/1.
Category of submission: original article.
This article is not based on a previous communication to a society or meeting.
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Abstract

Background: Gallstone related pathology (GRP) accounts for a significant proportion of general surgery admissions. The aim of this study is to investigate if seasonal variation for GRP admissions exist in England allowing improved resource allocation and planning.

Methods: This multicentre retrospective cohort study included only emergency adult (≥18 years old) admissions to acute secondary care with ICD-10 codes associated with gallstones between 01/01/2010 to 31/12/2019 in England using Hospital Episode Statistics data. Seasons were defined according to United Kingdom Met Office.

Results: A total of 396 879 GRP related admissions were recorded during the specified period, accounting for 1.44% of all emergency admissions. Our study suggests a significant seasonal peak in Summer (n=102 620) based cumulative admissions per season and a linear regression model ($p<0.001$), followed by Autumn (n=102 267), then Spring (n=97 807) and finally Winter (n=94 185). Spectral analysis confirmed there is seasonality in the emergency GRP admissions every 12 months. A forecasting model was shown to be reliable; all observed admissions for 2019 were within the 95% prediction intervals for each month for the proportion of emergency GRP admissions.

Discussion: Resource allocation towards the Summer months to target seasonal peaks in GRP should be considered.

Word count = 198

Introduction

Gallstone disease represents a significant health burden in the developed world, with 10-15% of the adult population developing gallstones at some point in their lifetime[1]. The large majority are asymptomatic (80%), however 1-4% of patients go on to develop symptoms per year[1,2]. Gallstone Related Pathology (GRP) accounts for a third of all emergency general surgery admissions and referrals in England[3]. Current guidance supports the practice of index admission laparoscopic cholecystectomy for symptomatic gallstone disease, based on the available evidence which suggests a clinical as well as fiscal advantage over delayed surgery[4]. A current Royal College of Surgeons England Cholecystectomy Quality Improvement Collaborative (Chole-QuIC) sets a target of 80% of eligible patients receiving a cholecystectomy within 8 days of index admission due to GRP [5]. Eligible patients include those who are fit enough for surgery presenting with biliary colic, cholecystitis or gallstone pancreatitis[6]. Furthermore, Endoscopic Retrograde Cholangiopancreatography (ERCP) is recommended within 72 hours for jaundice secondary to common bile duct stones or 24 hours for severe cholangitis or pancreatitis [7].

In practice this recommendation may be difficult to achieve due to resource and logistical limitations in centres recovering from delays in elective surgery due to the Severe Acute Respiratory Syndrome Coronavirus-2 (COVID – 19) pandemic. In light of these potential limitations, there is merit in investigating for predictable patterns in demand for surgical treatment of GRP, so as to allow for pre-emptive planning and distribution of 'hot gallbladder' lists.

The concept of temporal variation in acute surgical admissions has been explored. Emergency general surgery admissions for diverticulitis and appendicitis peak during summer months in the United States and the United Kingdom[8–10]. A similar summer spike

was seen in a large retrospective study in America exploring admissions based on diagnostic codes for acute cholecystitis between 2004 to 2011 (n= 353 927). Conversely, winter was the season with the lowest rate of admissions[9]. When reviewing cholecystectomy procedural activity similar patterns were found in a population based study involving 1 928 833 patients in Taiwan and a single centre retrospective study in Pakistan[11,12]. Of note, temperature was highly correlated with the cholecystectomy rate in Taiwan[11]. Evidence for seasonal variation in cholelithiasis related acute pancreatitis is mixed, although a single centre study has suggested a peak in Spring other single centre studies have suggested no seasonality [13–15]. There is no literature exploring the seasonal variation of acute cholecystitis in the United Kingdom. Furthermore, there is no study investigating the temporal variation for the overarching spectrum of gallstone disease. This also includes pathology such biliary colic, choledocholithiasis, gallstone pancreatitis and gallstone cholangitis. All diseases which warrant urgent or expedited surgical intervention as discussed earlier; often overwhelming our 'emergency lists' and leading to significant delays in patient treatment.

Gallstones occur due to an imbalance in the contents of bile including cholesterol, bilirubin and calcium salts. In Western society gallstones are largely composed of cholesterol[16]. Gallstones form due to the supersaturation of bile with cholesterol; bile acids cannot keep cholesterol in solution, so they become insoluble forming cholesterol crystals. This free cholesterol damages the gallbladder lining leading to hypomotility and mucus hypersecretion which in turn further promotes crystal nucleation. Gradual deposition of layers of cholesterol and mucus leads to the macroscopic formation of gallstones[17]. Seasonal changes in temperature, rainfall and humidity all impact pathogenesis in a range of diseases by affecting host, pathogen or both[11]. The exact aetiology of this seasonal variation is unclear and is likely a relationship between heterogenous extrinsic and patient intrinsic factors[18]. Specific to

gallstones, periodic changes in diet, hydration levels and physiology could have an impact on gallstone formation humans[11,19].

The aim of this study is to investigate if a seasonal variation for the spectrum of gallstone disease exists in England and to forecast future admissions. Perhaps knowledge of this will allow for better resource allocation and availability of ultrasound, Magnetic Resonance CholangioPancreatography (MRCP), ERCP and 'hot gallbladder' theatre lists during peak seasons. This will allow more timely and efficient treatment of patients, in keeping with guidelines, in an already stretched National Health Service (NHS) recovering from a public health emergency.

Methodology

Data Source

For this study we used anonymised patient information from Dr Foster Intelligence. This database is based on NHS Hospital Episode Statistics (HES) data and collects information on inpatient admissions from participating hospitals in England including demographic factors, diagnostic codes, methods of admission (elective or emergency), date of admission, length of stay and mortality. Participating hospital trusts (n=71) in this study are listed in appendix 1.

Patients

Once the data is pooled centrally, using Dr Foster software filters, specific inclusion criteria were defined based on age and International Classification of Diseases, Tenth Revision (ICD-10) codes. This retrospective cohort study included only emergency adult (≥18 years old) admissions to acute secondary care with ICD-10 codes associated with gallstones between 01/01/2010 to 21/12/2019. Specifically, any patients with an ICD-10 code related to GRP

included in the primary, secondary or tertiary diagnosis in their first ‘episode’ of a hospital admission ‘spell’ met the inclusion criteria. Specific note was made of the date of admission.

A hospital spell is a patient’s total length of stay in hospital for a single admission, it is made up of several episodes. An episode is a component of their inpatient stay under a specific ward or consultant meaning that several episodes form a spell. In this study spells were used as a measure of incidence instead of raw patient numbers as a patient can present more than once throughout the data collection period with GRP.

Definitions

The following ICD-10 codes were used to identify GRP as a reason for admission: K56.3 Gallstone ileus, K80.0 Calculus of gallbladder with acute cholecystitis, K80.1 Calculus of gallbladder with other cholecystitis, K80.2 Calculus of gallbladder without cholecystitis, K80.3 Calculus of bile duct with cholangitis, K80.4 Calculus of bile duct with cholecystitis, K80.5 Calculus of bile duct without cholangitis or cholecystitis, K81.0 Acute cholecystitis, K81.1 Chronic cholecystitis, K81.9 Cholecystitis, unspecified, K82.2 Perforation of gallbladder, K82.3 Fistula of gallbladder, K83.0 Cholangitis and K85.1 Biliary acute pancreatitis.

To explore seasonal variation seasons were defined according to United Kingdom Met Office. Spring comprised of March, April and May. Summer comprised of June, July and August. Autumn comprised of September, October and November. Winter included December, January and February.

Data Analysis

We analysed GRP in a monthly and seasonal basis. Data was presented as spells or admissions, however given the differing length of days in each season and to evaluate GRP

seasonal variation among all other emergency hospital admissions, we calculated the proportion of GRP admissions (GRPP%) using all adult emergency admissions as the denominator for each time period. There are several ways to assess seasonality in the statistical literature, in our analysis we considered a variety of measures to assess whether conclusions were consistent across methods.

Initial Data Cleaning An initial plot of GRP (Figure 1) and GRPP% indicates that structural breaks exist, which violate the assumptions of stationarity required for the statistical models in use. Upon inspection these were likely due to coding. We removed the structural breaks using changepoint analysis[20,21]. This formed a linear trend, permitting us to estimate the seasonal variation using all available data. A change in linear trend model was fit to the GRPP using the EnvCpt R[22–24] package on CRAN[25]. The trend is important for forecasting future case load and thus the fitted change in trend was normalized such that the overall trend for the data was that in the final section of the original data.

Seasonality Using Seasonal Factors An often-used method for assessing whether seasonal effects are present in data is to fit a linear regression model with seasonal dummy variables. Due to the trend present in the GRPP data, we have coefficients for the baseline (intercept+Spring), linear trend, additional summer load, additional autumn load and additional winter load, resulting in a model with 5 estimated coefficients. To test the significance of the seasonal factor we consider the results from ANOVA, Likelihood Ratio test and Wald Test with robust standard errors. These tests can be found in the lrtest R[26] package and the robust standard errors in the sandwich R[27] package. The three tests have slightly varying assumptions and so disagreement between the test outcomes is informative.

Seasonality Using Spectral Analysis An alternative approach to using arbitrary seasonal dummy variables is to use spectral analysis to identify the periodicity (or lack thereof) in the

GRPP data. To identify seasonality we plot the periodogram and identify "peaks". The significance of these peaks can be assessed using the Webel-Ollech test which combines results from the QS and KW tests in the seastests R[28] package.

Forecasting Future Load As well as understanding the patterns in GRPP we wish to be able to forecast future GRPP loads. Whilst spectral analysis is helpful to identify a yearly seasonal pattern is present we need to embed this knowledge into a model in order to forecast future GRPP values. For this we will use a Seasonal Auto-Regressive Moving Average model with exogenous variables (SARMAX). This models our current value of GRPP as a function of both the recent past (AR), recent errors in the model (MA) and also seasonal variants of these (S) as well as allowing for trend components (X). The forecast[29] package in R has a function auto.arima that conveniently assesses which parts of the SARMAX model are important for a given dataset and the degree to which the past is informative. The suite of functions also allow us to forecast future values from the fitted model and assess the accuracy of our forecasts[30].

Results

In our study a total of 349 786 patients were admitted with emergency GRP nationally over a decade. They accounted for 396 879 emergency admissions or spells during this time period. This equated to 1.1 spells per patient. The majority of admissions were due to females, 59.4% (n spells=235 690). The modal age for GRP admissions were between 75-84 years old. In general, a greater proportion of GRP admissions were accounted for by increasing age. The vast majority of patients were also Caucasian, 85.4% (n spells=338 846). The most common reason for admission was calculus of gallbladder with acute cholecystitis, accounting for 18.5% (n spells=73 276). Other common reasons for admission included: calculus of gallbladder without cholecystitis (13.6%, n spells=54 079), calculus of gallbladder with other

cholecystitis (13.5%, n spells=53 501), calculus of bile duct without cholangitis and cholecystitis (12.7%, n spells=50 286). Of note biliary acute pancreatitis accounted for almost one tenth of admissions (9.8%, n spells=38 774). Indeed, a cholecystitis associated ICD-10 code accounted for 49.1% (n=195 058). The median length of stay in hospital for all patients admitted with GRP was 5 days (interquartile range = 6 days). For admissions with GRP in their initial episode, there was a mortality rate of 2.6% (n spells=10 183).

A total of 27 618 637 emergency admissions were also recorded over the same time period nationally. Therefore, GRP accounted for 1.44% (n=396 879) of all emergency admissions between 01/01/2010 to 31/12/2019. There was a general increasing trend in the number of GRP emergency admissions with time as shown in *Figure 1*.

Exploratory Analysis From 2010 to 2019 emergency GRP admissions were lowest over February (n=29 935) and highest in October (n=34 809), a 16.2% increase. This is shown in *Table 2*. The proportion of emergency gallstone admissions was lowest in January at 1.38% (31 492/2 290 287 inpatient admissions) and highest in August 1.49% (34 633/2 327 973), a significant increase of 0.11%, (1d.f., N=4 684 385) = 103.8347, $p<0.001$.

GRP had the lowest number of admissions in Winter (n=94 185) between 2010 and 2019 as highlighted in *Table 3*. The highest number of admissions cumulatively occurred over the Summer months (n=102 620). This accounts for an 8.96% increase. When considering GRP admissions as a proportion of all emergency admissions (GRPP%), Autumn and then Summer see the highest proportions at 1.47% (102 267/6 961 395) and 1.46% (102 620/7 011 001) respectively which are significant when compared to the lower Spring, 1.42% (97 807/6 904 013) and Winter, 1.40% (94 185/6 742 228) months using X^2, (1.d.f., $p<0.05$). This is clearly depicted in *Figure 2.* Of note, similar to the trend in GRP admissions, all other

emergency admissions are greatest in the Summer, then Autumn, followed by Spring and then Winter.

Note that to evaluate our forecast we split the data into two parts, the first 9 years for model building and the final year for testing our forecast. All the remaining results are for analysis using the first 9 years of data.

Seasonality Using Seasonal Factors The linear regression model with dummy seasonal factors reflects our initial exploratory analysis, identifying the Winter months as those with the lowest incidence (-0.0314 difference from Spring) followed by Spring (0.859 baseline), Autumn (0.017 difference from Spring) and Summer with the highest incidence (0.0314 difference from Spring). The ANOVA ($p<0.001$), likelihood ratio ($p<0.001$) and Wald ($p<0.001$) tests were all significant at the 5% level. This indicates that the seasonal dummy variables were beneficial to include in the model. The diagnostics from the linear model e.g. residuals vs fitted values, Normal Q-Q plot, leverage, were all reasonable.

Seasonality Using Spectral Analysis The peak of the periodogram is at the yearly frequency (1/12). Testing the significance of this yearly seasonal frequency, the QS ($p=0.002$), QS-R ($p<0.001$), and KW-R ($p<0.001$) seasonality tests all reject the null of no seasonality at the 5% level. This indicates that there is seasonality within the data.

Forecasting Future Load The SARMAX model chosen by the auto.arima() function is one which contains an intercept and slope (as for the linear regression) with an Auto-Regressive model of order 1 i.e. the current percentage depends on the previous months percentage, as well as a Seasonal Auto-Regressive model of order 1 i.e. the current percentage also depends on last years percentage in the same month. The full model is written as:

$$GRPP_t = 0.8613 + 0.0068*(\#\text{ months since Jan 2010}) + 0.3738*GRPP_{t-1} + 0.3306*GRPP_{t-12}$$

Using the model to forecast the final 12 months of data (2019) we obtain the results in Table 4. Each of the observed GRPP% are within the 95% prediction intervals. The root mean squared error (RMSE) of the predictions is 0.01918 and the mean percentage error is 0.1445.

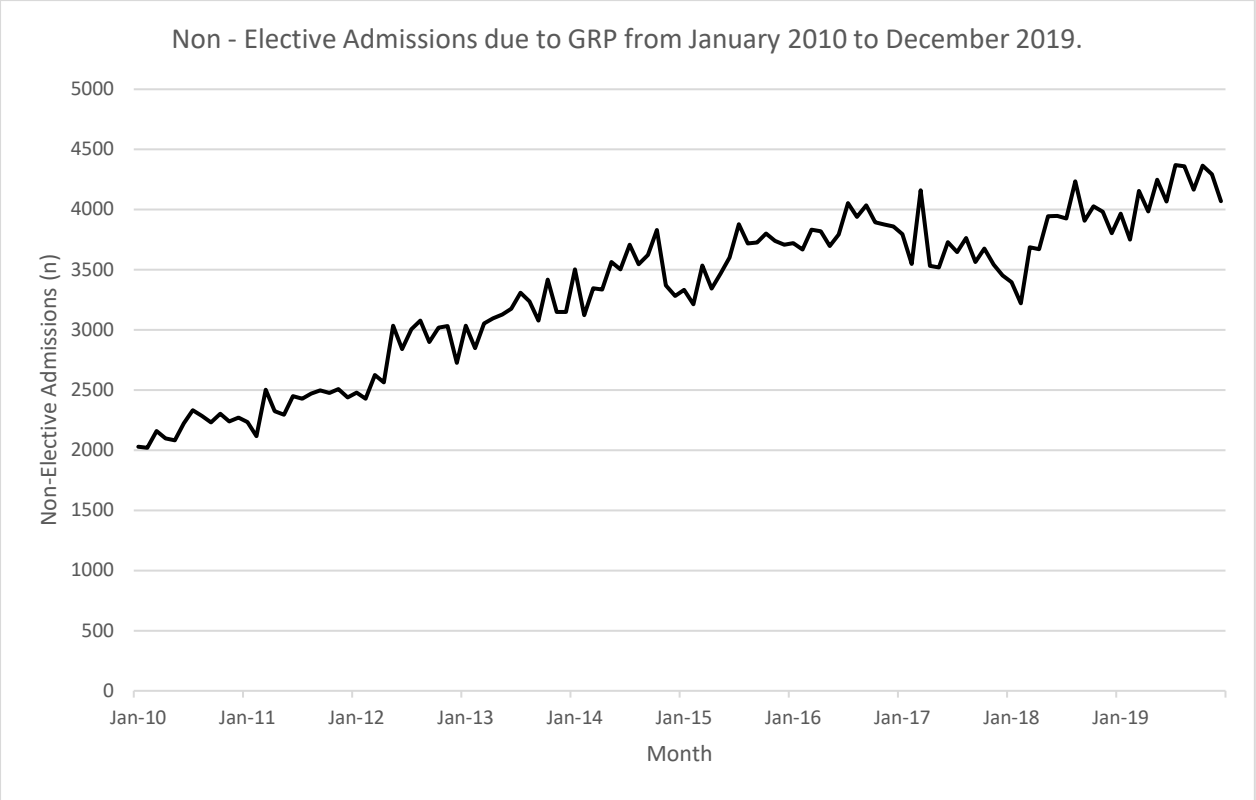

Figure 1 Displays overall incidence of emergency gallstone related admissions from 2010 to 2019.

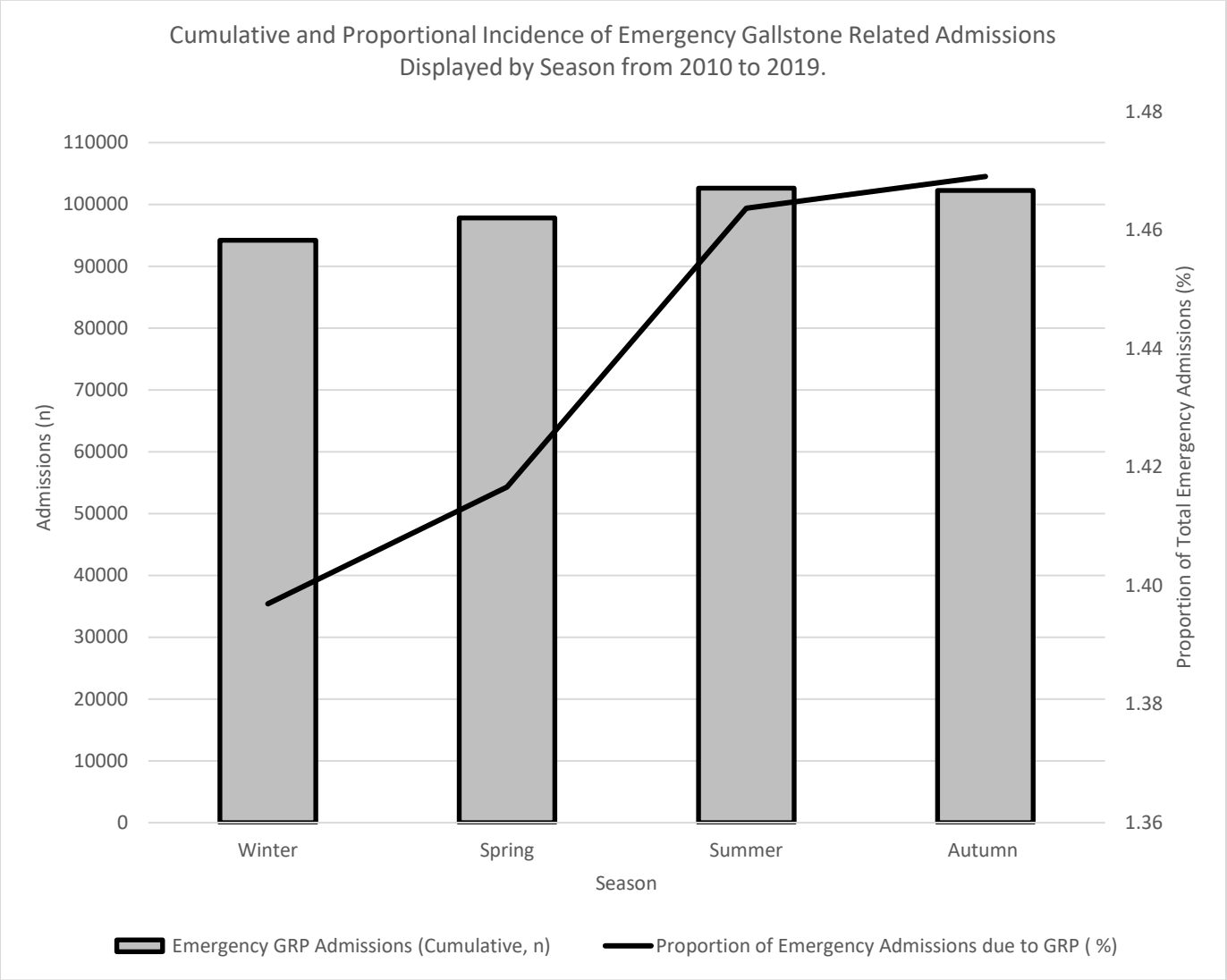

Figure 2 Illustrates seasonal variation in emergency GRP admissions (2010 – 2019).

Discussion

Our national retrospective study identifies a seasonal summer peak in the admissions of emergency GRP to secondary care across England from 2010 to 2019. GRP admissions are lowest during Winter. This conclusion is based on cumulative admissions per season and a linear regression model that suggests greatest GRP admissions during Summer, followed by Autumn, then Spring and lowest in Winter. Of note, the season which accounted for the greatest GRPP% was Autumn (1.47%, n= 102 267/6 961 395), closely followed by Summer

(1.46%, n= 102 620/7 011 001). Furthermore, spectral analysis confirmed there is seasonality in the emergency GRP admissions every 12 months. As per previous population-based studies examining the incidence of cholecystitis and laparoscopic cholecystectomy in America and Taiwan respectively, a peak was seen in Summer, then Autumn with a trough in Winter[9,11]. No other study has examined the periodic fluctuations in the whole spectrum of gallstone disease.

Using data from this study, greater resource allocation for the diagnosis and treatment of GRP can be coordinated towards Summer and Autumn. This includes an increased number of ultrasound and MRCP slots dedicated towards general surgery services across England. Additionally extra ERCP and 'hot gallbladder' lists could be accommodated to ensure compliance with NICE and Chole-QuIC targets [5,7]. Moreover, the SARMAX model used to forecast future admissions for GRP in England has been shown to be reliable; all observed admissions for 2019 were within the 95% prediction intervals for each month for GRPP%. Therefore, using the equation with contemporary admission values, GRPP% can be predicted to aid revision of resource allocation on a monthly basis.

Our study shows a steady increase in the number of emergency GRP admissions over the last decade. Other studies have also reported a similar increase in overall emergency general surgery and cholecystitis admissions [9,11]. From a public health and resource allocation perspective this steady increase is concerning as GRP already accounts for a third of all emergency general surgery admissions and referrals already [3]. Therefore, preventative measures against known risk factors for gallstones should be touted. Promoting against an unhealthy diet based on fat, refined carbohydrates and low fibre, with limited exercise, can help plateau this trend and it may be reasonable to incorporate gallstone and their painful sequalae in public advertisement campaigns. From a resource viewpoint more priority should

be given in training and hiring surgeons, physicians and radiologists who are able to treat GRP surgically, endoscopically and, or radiologically.

The majority of admissions were accounted for by females in keeping with previous studies[11]. In developing countries there has been a shift towards a more elderly population on average. Pathology such as cholecystitis peaks in the elderly[9,11] and therefore the positive correlation between age and proportion of emergency GRP admissions with a peak at 75 – 84 years old is unsurprising. Given the higher risk of anaesthetic and post-operative complications associated with frailty and multiple co-morbidities, perhaps elderly patients are not undergoing a cholecystectomy. This in turn could be leading to repeated admissions. Perhaps greater emphasis should therefore be placed on diagnosing and treating symptomatic patients earlier in their lifetime with a prompt and efficient service.

Cumulatively all ICD – 10 codes related to cholecystitis accounted for almost half of the emergency GRP admissions in England from 2010 to 2019. As mentioned, our study highlights a peak of admissions during Summer which is comparable to other population-based studies[9,11]. Therefore, a common aetiological process may play a role. Over the past decade in England Summer has recorded the highest mean temperature, followed by Autumn, then Spring and finally Winter[31]. Interestingly this pattern echoes the incidence of GRP emergency admissions. In Taiwan it was demonstrated that a greater temperature was associated with a peak in cholecystectomy procedures[11]. Bacterial infection and associated release of inflammatory mediators is thought to drive acute cholecystitis; indeed post-operative specimens have grown both gram negative and positive enteric organisms[32]. Studies have also highlighted a seasonal variation in the incidence of gram positive (*Staphylococcus-aureus*)[33] and gram negative (mainly *Escherichia coli*)[34,35], with a greater incidence during warmer temperatures. Perhaps periodic fluctuations in bacterial pathogens due to temperature are playing a role in the GRP seasonal variation, meaning that more

patients are suffering from cholecystitis or any GRP with an infective component therefore requiring admission. However, infection is also related to host behavioural and physiological characteristics not just due to pathogen alone and given these complex interactions are unlikely the driving force behind the seasonality in GRP alone[11,12].

It also does not explain an important proportion of the study traditionally not due to an infective component such as biliary colic, choledocholithiasis and biliary acute pancreatitis. Cholecystokinin is released by the proximal small bowel in response to fatty and amino acids in a meal, this in turn causes contraction of the gallbladder in order to release stored bile to emulsify fatty foods to aid digestion. If a gallstone is present, it may lodge against the neck of the gallbladder or cystic duct causing the classically described colicky pain. It is therefore advised that patients with symptomatic gallstones refrain from fatty foods[7]. Traditionally in England, the winter months are thought to be a period of indulgence with palatable energy dense foods. In Western societies, over the Christmas period weight gain is noted[36,37], particularly in the UK[38], and blood lipid levels(including cholesterol)[39] are also greater potentially exposing patients to triggers of GRP symptoms. In this study during Winter, emergency GRP admission rates were at their lowest suggesting that seasonal trends in weight gain, lipid levels and diet may not be the cause. Of note, weight loss confers an increased risk of gallstone formation, particularly in the obese population[40,41]. As noted, weight gain is seen during the Winter months, and indeed weight loss in the Northern hemisphere is typically observed during the late Summer months[42]. Therefore, prompting the formation of gallstones during Summer and Autumn, leading to symptoms and thus potentially contributing to the observed peak in admissions during these seasons. Similarly, during Summertime dehydration levels are greatest due to temperature and increased activity levels[43]. This can promote gallstone formation via two mechanisms. Firstly, colonic transit can be slowed due to dehydration[8] promoting faecal stasis leading to greater absorption levels

of deoxycholic acid in the colon. This in turn causes the liver to secrete more cholesterol into bile[44]. Furthermore, dehydration can cause reduced absorption of water in the gallbladder promoting supersaturation of bile with cholesterol. This acts as a catalyst for gallstone formation, leading to an increased likelihood for patients to present with GRP in Summer[11]. Indeed Math et al in 1986 suggested that greater fluid intake could play a possible role in gallstone prevention[19]. Conversely a cross sectional study exploring the fasting months of Ramadan in Iran and the incidence of calculous cholecystitis over a 5 year period suggested no link[45].

Strengths of our study include the size, multicentre nature, duration of observation and the multiple statistical modelling techniques used. This makes the seasonal variation observed less likely attributable to chance. However, limitations include the variability and inaccuracies in coding GRP using HES data. Additionally, by using admission codes, as oppose to diagnostic codes on discharge our sample may overestimate the true incidence of GRP. The use of primary, secondary and tertiary diagnosis for the first episode of the hospital admission was used to ensure GRP was not missed, however patients with known gallstones may be included in the study due to coding of their comorbidities during an admission which was not related to GRP, again potentially overestimating the true incidence of emergency GRP. However, these errors are unlikely to show the seasonal pattern demonstrated. Nevertheless, this study only reviewed patients admitted to hospital. Patients discharged and or managed in the community were omitted, underestimating of the true incidence of GRP. From an aetiological view, it may be feasible to analyse the incidence the separate diseases within the spectrum of GRP with direct comparison to temperature, humidity, sunlight hours and other factors that define seasonality. Indeed, if national data on the incidence of bacterial pathogens is available, it could be added as a covariate in a future regression model which could confirm it is a driving factor in seasonal variation in infective components of GRP.

Conclusion

In this national multicentre study in England, there was a significant peak in GRP during the Summer months and a trough in the Winter. Seasonality was also confirmed by spectral analysis. Furthermore, there is a steady increase in the number of GRP admissions. Given the significant burden that GRP already places on the NHS, with the added strain of COVID-19 delaying elective operations perhaps there needs to be greater emphasis on resource allocation towards public health campaigns, whilst training and hiring more doctors who can treat GRP. Particularly during the Summer months to target seasonal peaks; allowing safe and timely intervention for patients vulnerable to the risks that GRP can pose.

Acknowledgements

Dr Killick gratefully acknowledges funding from EPSRC under grant EP/T014105/1.

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Tables

Table 1 Patient demographic data.

Demographic data		N (spells)	%
Gender	Female	235,690	59.4
	Male	161,173	40.6
	Not specified	16	0.0
Age (years)	18-24	12,138	3.1
	25-34	32,857	8.3
	35-44	36,942	9.3
	45-54	51,298	12.9
	55-64	58,539	14.7
	65-74	76,375	19.2
	75-84	81,483	20.5
	85+	47,247	11.9
Ethnicity	White	338,846	85.4
	Mixed	1,779	0.4
	Asian or Asian British	16,488	4.2
	Black or Black British	5,819	1.5
	Other Ethnic Groups	33,947	8.6
Diagnosis	K56.3 Gallstone ileus	2,649	0.7
	K80.0 Calculus of gallbladder with acute cholecystitis	73,276	18.5
	K80.1 Calculus of gallbladder with other cholecystitis	53,501	13.5
	K80.2 Calculus of gallbladder without cholecystitis	54,079	13.6
	K80.3 Calculus of bile duct with cholangitis	22,265	5.6
	K80.4 Calculus of bile duct with cholecystitis	13,814	3.5
	K80.5 Calculus of bile duct without cholangitis or cholecystitis	50,286	12.7
	K81.0 Acute cholecystitis	33,276	8.4
	K81.1 Chronic cholecystitis	4,060	1.0
	K81.9 Cholecystitis unspecified	17,131	4.3
	K82.2 Perforation of gallbladder	3,652	0.9
	K82.3 Fistula of gallbladder	290	0.1
	K83.0 Cholangitis	29,826	7.5
	K85.1 Biliary acute pancreatitis	38,774	9.8
Median LOS* days (Q1, Q3)**		5	(3, 9)
Mortality	No	386,176	97.3
	Yes	10,183	2.6
	Unknown	520	0.1

Abbreviations: *LOS= Length of stay in hospital for admission, **Q1, Q3 = Quartiles 1 and 3

Table 2 Monthly variation in emergency GRP admissions.

	Emergency GRP Admissions (Cumulative, n)	Emergency GRP Admissions per Month (Mean)	Other Emergency Admissions (Cumulative, x10^6, 2.d.p)	Proportion of Emergency Admissions due to GRP (%)
Jan	31 492	3149	2.26	1.38
Feb	29 935	2994	2.10	1.41
Mar	33 054	3305	2.30	1.42
Apr	31 773	3177	2.20	1.42
May	32 980	3298	2.31	1.41
Jun	33 331	3333	2.27	1.45
Jul	34 656	3466	2.35	1.46
Aug	34 633	3463	2.29	1.49
Sep	33 724	3372	2.26	1.47
Oct	34 809	3481	2.34	1.47
Nov	33 734	3373	2.26	1.47
Dec	32 758	3276	2.29	1.41
Total	**396 879**		**27 221 758**	

	Emergency GRP Admissions (Cumulative, n)	Emergency GRP Admissions per Month (Mean)	Other Emergency Admissions (Cumulative, x 10^6, 2.d.p)	Proportion of Emergency Admissions due to GRP (%)
Winter	94 185	3140	6.65	1.40
Spring	97 807	3260	6.81	1.42
Summer	102 620	3421	6.91	1.46
Autumn	102 267	3409	6.86	1.47

Table 3 Seasonal variation in emergency GRP admissions.

*GRPP% 2019	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Observed	1.56	1.62	1.65	1.61	1.63	1.64	1.65	1.70	1.67	1.65	1.71	1.62
Forecast	1.574	1.608	1.626	1.619	1.631	1.639	1.647	1.668	1.662	1.660	1.685	1.660
95% Forecast Interval	1.501, 1.648	1.530, 1.686	1.548, 1.705	1.540, 1.698	1.552, 1.709	1.560, 1.717	1.568, 1.725	1.589, 1.746	1.584, 1.741	1.582, 1.739	1.606, 1.763	1.581, 1.738

*Table 4 Forecasts and observed values of emergency GRP admissions for 2019. * GRP admissions as a proportion of all emergency admissions.*

Appendix 1 – NHS Trusts included in study

UNIVERSITY HOSPITALS BIRMINGHAM NHS FOUNDATION TRUST	UNIVERSITY HOSPITALS OF LEICESTER NHS TRUST
LEEDS TEACHING HOSPITALS NHS TRUST	BLACKPOOL TEACHING HOSPITALS NHS FOUNDATION TRUST
LIVERPOOL UNIVERSITY HOSPITALS NHS FOUNDATION TRUST	HAMPSHIRE HOSPITALS NHS FOUNDATION TRUST
MANCHESTER UNIVERSITY NHS FOUNDATION TRUST	KETTERING GENERAL HOSPITAL NHS FOUNDATION TRUST
OXFORD UNIVERSITY HOSPITALS NHS FOUNDATION TRUST	GATESHEAD HEALTH NHS FOUNDATION TRUST
UNIVERSITY HOSPITALS OF NORTH MIDLANDS NHS TRUST	CHELSEA AND WESTMINSTER HOSPITAL NHS FOUNDATION TRUST
EAST KENT HOSPITALS UNIVERSITY NHS FOUNDATION TRUST	UNIVERSITY HOSPITALS COVENTRY AND WARWICKSHIRE NHS TRUST
PENNINE ACUTE HOSPITALS NHS TRUST	EAST SUSSEX HEALTHCARE NHS TRUST
UNIVERSITY HOSPITALS OF DERBY AND BURTON NHS FOUNDATION TRUST	THE ROTHERHAM NHS FOUNDATION TRUST
NORTHUMBRIA HEALTHCARE NHS FOUNDATION TRUST	ROYAL BERKSHIRE NHS FOUNDATION TRUST
YORK TEACHING HOSPITAL NHS FOUNDATION TRUST	LEWISHAM AND GREENWICH NHS TRUST
SHEFFIELD TEACHING HOSPITALS NHS FOUNDATION TRUST	MEDWAY NHS FOUNDATION TRUST
COUNTY DURHAM AND DARLINGTON NHS FOUNDATION TRUST	THE ROYAL WOLVERHAMPTON NHS TRUST
MID YORKSHIRE HOSPITALS NHS TRUST	DARTFORD AND GRAVESHAM NHS TRUST
SOUTH TYNESIDE AND SUNDERLAND NHS FOUNDATION TRUST	SHERWOOD FOREST HOSPITALS NHS FOUNDATION TRUST
PORTSMOUTH HOSPITALS NHS TRUST	ASHFORD AND ST PETER'S HOSPITALS NHS FOUNDATION TRUST
UNITED LINCOLNSHIRE HOSPITALS NHS TRUST	WEST HERTFORDSHIRE HOSPITALS NHS TRUST
FRIMLEY HEALTH NHS FOUNDATION TRUST	GREAT WESTERN HOSPITALS NHS FOUNDATION TRUST
ROYAL FREE LONDON NHS FOUNDATION TRUST	BUCKINGHAMSHIRE HEALTHCARE NHS TRUST
SHREWSBURY AND TELFORD HOSPITAL NHS TRUST	THE PRINCESS ALEXANDRA HOSPITAL NHS TRUST
BARTS HEALTH NHS TRUST	EAST AND NORTH HERTFORDSHIRE NHS TRUST
WESTERN SUSSEX HOSPITALS NHS FOUNDATION TRUST	THE DUDLEY GROUP NHS FOUNDATION TRUST
EAST LANCASHIRE HOSPITALS NHS TRUST	EPSOM AND ST HELIER UNIVERSITY HOSPITALS NHS TRUST
NORFOLK AND NORWICH UNIVERSITY HOSPITALS NHS FOUNDATION TRUST	BEDFORDSHIRE HOSPITALS NHS FOUNDATION TRUST
BARKING HAVERING AND REDBRIDGE UNIVERSITY HOSPITALS NHS TRUST	COUNTESS OF CHESTER HOSPITAL NHS FOUNDATION TRUST
LONDON NORTH WEST UNIVERSITY HEALTHCARE NHS TRUST	SOUTHEND UNIVERSITY HOSPITAL NHS FOUNDATION TRUST
DONCASTER AND BASSETLAW TEACHING HOSPITALS NHS FOUNDATION TRUST	WEST SUFFOLK NHS FOUNDATION TRUST
HULL UNIVERSITY TEACHING HOSPITALS NHS TRUST	WALSALL HEALTHCARE NHS TRUST
KING'S COLLEGE HOSPITAL NHS FOUNDATION TRUST	MILTON KEYNES UNIVERSITY HOSPITAL NHS FOUNDATION TRUST
UNIVERSITY HOSPITALS PLYMOUTH NHS TRUST	MID ESSEX HOSPITAL SERVICES NHS TRUST
GLOUCESTERSHIRE HOSPITALS NHS FOUNDATION TRUST	ROYAL SURREY COUNTY HOSPITAL NHS FOUNDATION TRUST
NORTHERN LINCOLNSHIRE AND GOOLE NHS FOUNDATION TRUST	BARNSLEY HOSPITAL NHS FOUNDATION TRUST
NOTTINGHAM UNIVERSITY HOSPITALS NHS TRUST	STOCKPORT NHS FOUNDATION TRUST
UNIVERSITY HOSPITALS BRISTOL AND WESTON NHS FOUNDATION TRUST	JAMES PAGET UNIVERSITY HOSPITALS NHS FOUNDATION TRUST
WORCESTERSHIRE ACUTE HOSPITALS NHS TRUST	NORTH MIDDLESEX UNIVERSITY HOSPITAL NHS TRUST
ROYAL CORNWALL HOSPITALS NHS TRUST	AIREDALE NHS FOUNDATION TRUST
CALDERDALE AND HUDDERSFIELD NHS FOUNDATION TRUST	SALISBURY NHS FOUNDATION TRUST
UNIVERSITY HOSPITAL SOUTHAMPTON NHS FOUNDATION TRUST	NORTHAMPTON GENERAL HOSPITAL NHS TRUST
EAST SUFFOLK AND NORTH ESSEX NHS FOUNDATION TRUST	SOUTHPORT AND ORMSKIRK HOSPITAL NHS TRUST
THE NEWCASTLE UPON TYNE HOSPITALS NHS FOUNDATION TRUST	THE QUEEN ELIZABETH HOSPITAL KING'S LYNN NHS FOUNDATION TRUST
CAMBRIDGE UNIVERSITY HOSPITALS NHS FOUNDATION TRUST	EAST CHESHIRE NHS TRUST
UNIVERSITY HOSPITALS OF MORECAMBE BAY NHS FOUNDATION TRUST	GUY'S AND ST THOMAS' NHS FOUNDATION TRUST
MAIDSTONE AND TUNBRIDGE WELLS NHS TRUST	CROYDON HEALTH SERVICES NHS TRUST
BRADFORD TEACHING HOSPITALS NHS FOUNDATION TRUST	ST GEORGE'S UNIVERSITY HOSPITALS NHS FOUNDATION TRUST
NORTH BRISTOL NHS TRUST	TAMESIDE AND GLOSSOP INTEGRATED CARE NHS FOUNDATION TRUST
ST HELENS AND KNOWSLEY TEACHING HOSPITALS NHS TRUST	UNIVERSITY COLLEGE LONDON HOSPITALS NHS FOUNDATION TRUST
WIRRAL UNIVERSITY TEACHING HOSPITAL NHS FOUNDATION TRUST	YEOVIL DISTRICT HOSPITAL NHS FOUNDATION TRUST
TAUNTON AND SOMERSET NHS FOUNDATION TRUST	WYE VALLEY NHS TRUST
NORTH CUMBRIA INTEGRATED CARE NHS FOUNDATION TRUST	KINGSTON HOSPITAL NHS FOUNDATION TRUST
NORTH TEES AND HARTLEPOOL NHS FOUNDATION TRUST	SOUTH WARWICKSHIRE NHS FOUNDATION TRUST
SOUTH TEES HOSPITALS NHS FOUNDATION TRUST	NORTHERN DEVON HEALTHCARE NHS TRUST
ROYAL DEVON AND EXETER NHS FOUNDATION TRUST	GEORGE ELIOT HOSPITAL NHS TRUST
LANCASHIRE TEACHING HOSPITALS NHS FOUNDATION TRUST	POOLE HOSPITAL NHS FOUNDATION TRUST
SURREY AND SUSSEX HEALTHCARE NHS TRUST	DORSET COUNTY HOSPITAL NHS FOUNDATION TRUST
ROYAL UNITED HOSPITALS BATH NHS FOUNDATION TRUST	THE HILLINGDON HOSPITALS NHS FOUNDATION TRUST
TORBAY AND SOUTH DEVON NHS FOUNDATION TRUST	BEDFORD HOSPITAL NHS TRUST
CHESTERFIELD ROYAL HOSPITAL NHS FOUNDATION TRUST	HARROGATE AND DISTRICT NHS FOUNDATION TRUST
BOLTON NHS FOUNDATION TRUST	WHITTINGTON HEALTH NHS TRUST
SANDWELL AND WEST BIRMINGHAM HOSPITALS NHS TRUST	SOUTH LONDON HEALTHCARE NHS TRUST
SALFORD ROYAL NHS FOUNDATION TRUST	HOMERTON UNIVERSITY HOSPITAL NHS FOUNDATION TRUST
BRIGHTON AND SUSSEX UNIVERSITY HOSPITALS NHS TRUST	ISLE OF WIGHT NHS TRUST

BASILDON AND THURROCK UNIVERSITY HOSPITALS NHS FOUNDATION TRUST	MID STAFFORDSHIRE NHS FOUNDATION TRUST
MID CHESHIRE HOSPITALS NHS FOUNDATION TRUST	THE CHRISTIE NHS FOUNDATION TRUST
WRIGHTINGTON WIGAN AND LEIGH NHS FOUNDATION TRUST	THE ROYAL MARSDEN NHS FOUNDATION TRUST
IMPERIAL COLLEGE HEALTHCARE NHS TRUST	ROYAL BROMPTON & HAREFIELD NHS FOUNDATION TRUST
THE ROYAL BOURNEMOUTH AND CHRISTCHURCH HOSPITALS NHS FOUNDATION TRUST	THE CLATTERBRIDGE CANCER CENTRE NHS FOUNDATION TRUST
NORTH WEST ANGLIA NHS FOUNDATION TRUST	THE ROBERT JONES & AGNES HUNT ORTHOPAEDIC HOSPITAL NHS FOUNDATION TRUST
WARRINGTON AND HALTON TEACHING HOSPITALS NHS FOUNDATION TRUST	ROYAL PAPWORTH HOSPITAL NHS FOUNDATION TRUST
BIRMINGHAM WOMEN'S AND CHILDREN'S NHS FOUNDATION TRUST	LIVERPOOL WOMEN'S NHS FOUNDATION TRUST
LIVERPOOL HEART AND CHEST HOSPITAL NHS FOUNDATION TRUST	ROYAL NATIONAL ORTHOPAEDIC HOSPITAL NHS TRUST
THE WALTON CENTRE NHS FOUNDATION TRUST	