

The scars of time: the disappearance of peptic ulcer-related pyloric stenosis through the 20th century

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ABSTRACT

Background: The changing pattern of haemorrhage and perforation from peptic ulcer disease is well documented but little is known about pyloric stenosis, the third complication of the disease.

Methods: We reviewed records relating to definitive operations (with intent to cure) for peptic ulcer disease carried out in York, UK from 1929–1997. We categorised the patients as pyloric stenosis and no pyloric stenosis based on findings at operation and examined the change in total number of cases with pyloric stenosis and proportion of cases with pyloric stenosis, by year of operation and by decade of birth. To place our results in perspective, we reviewed world literature to examine rates of pyloric stenosis as a percentage of operative cases reported in other case series in the 20th century.

Results: 4178 patients were included in the analysis; 3697 without pyloric stenosis and 481 with pyloric stenosis (11.5%). Analysis by birth cohort showed that the proportion found to have pyloric stenosis at surgery fell from 17% in the first cohort (birth 1880–89) to only 2.9% in the last cohort (birth 1950–59; $p < 0.001$). Mean age at operation fell more steeply for those with pyloric stenosis: 74 to 30 years vs. 65 to 28 years ($p < 0.001$). The trend of final decline started before the introduction of modern medical treatment. Review of similar case series from across the world shows a similar decline in the proportion of peptic ulcer cases showing pyloric stenosis at operation.

Conclusion: The reduction in pyloric stenosis over the last several decades is disproportionately greater than the change seen in peptic ulcer disease requiring surgery. Our findings suggest that this reduction in pyloric stenosis is largely the result of the changing natural history of the disease rather than due to the introduction of acid-suppressing medication.

KEYWORDS birth cohort, fibrosis, history, peptic ulcer disease, pyloric stenosis, surgery

DECLARATION OF INTERESTS No conflict of interest declared.

INTRODUCTION

Pyloric stenosis (PS), still common in the mid-20th century, appeared to reduce in incidence in the latter half of the century. Anecdotally, its decline appeared to outstrip the fall in admissions for haemorrhage and perforation, the other complications of peptic ulcer disease (PUD), which continue to pose major problems.^{1,2} This study spans 1929–1997, a period which coincided with major changes in the frequency of ulcer disease and the continuing evolution of both surgical and medical treatment; histamine H₂-receptor antagonists (H₂RA) were introduced in November 1976 and proton pump inhibitors (PPI) in October 1989, which revolutionised medical management. The period was also one of great socio-economic improvement, with parallel changes in diet, hygiene and physical activity. The creation of the National Health

Service in the UK in 1948 also had a major bearing on access to medical care.

It was against these major developments that the changing pattern of haemorrhage and perforation in PUD came to be well described, but in contrast, much less is known about how rates of PS have varied with time. This report, which aims to bridge this gap in knowledge, was possible only because we were able to access data collected prospectively and systematically over many decades. Such examples are rare but provide unequalled opportunities to examine secular trends in disease over long periods.

Our aims, based on findings at operation, were to compare the numbers of patients in whom PS was seen,

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as opposed to those where it was not (No-PS). This allowed us to gain insight into the impact of modern medical therapies, to examine whether the period of birth influenced operation numbers and if changes were similar for those with and without PS. Finally, our aim was to place our observations in a wider global context from reports throughout the 20th century.

METHODS

We conducted an analysis of prospectively collected data pertaining to patients operated on for PUD in a single centre; our observations are based on patients both with and without PS. We also conducted a structured literature review to ascertain changes in reported prevalence of PS worldwide over the last century.

Source of data

The York Peptic Ulcer Research Trust (YPURT) database holds information on all definitive operations (i.e. with intent to cure) for PUD in York from 1929 to 1997. Patients were drawn mainly from the local population within a single health district, both before and after the inception of the National Health Service. Arthur HC Visick, based in York, was a pioneer of systematic follow-up and closely observed the long-term outcome of all his peptic ulcer patients operated on from 1929.³ Together with later colleagues he developed a system of standardised data collection in structured research records which commenced at the time of operation and were updated regularly. Being research-focused these documents contained considerably more detail than the hospital's case notes, and were kept separately. Visick's colleagues continued the programme following his death in 1949. In 1952 the YPURT was formed to sustain the programme and to maintain life-long follow-up.

Robert Hall became the YPURT clinical co-ordinator and curator in 1971. He filled gaps in the early information using archived records and has continued to do so since his retirement in 1998. Every research record was examined and key data were entered in to pre-defined spreadsheet fields. A specific field recorded whether or not PS was present at operation. Further information on the historical background of YPURT is available from the authors. The first operation recorded was carried out on 6 February 1929, and the last on 30 October 1997. The first instance of PS was noted on 18 November 1935, and the last on 26 October 1994.

Inclusion and exclusion criteria

The type of surgery was recorded in the database which included only those who had undergone definitive operations for PUD at York. Operations were of three types: partial or total gastrectomy, vagotomy and its variations, and gastroenterostomy alone.

We excluded cases where details of the operations were not clearly recorded and cases who had surgery elsewhere but were transferred to York for follow-up. We also excluded patients who had emergency surgery to control haemorrhage or to repair a perforation but without a definitive procedure, which had been erroneously entered in the database. Operations for congenital PS were not included in the database.

Pyloric stenosis: definition

We have used the general term 'pyloric stenosis' to cover the various descriptions in the literature, their shared feature being obstruction. Descriptions include obstruction resulting from any combination of an active ulcer or scar(s), varying degrees of fibrosis, and distortion affecting the pylorus at its inlet, channel, outlet, or indeed the whole structure. A single clinician (RH) experienced in peptic ulcer surgery reviewed all case records and adjudicated the presence of established PS, confirmed at operation to have hypertrophy or dilatation of the stomach and narrowing of the gastric outlet. The clinical or radiological picture alone did not determine categorisation.

Analysis

Two groups were compared, those with PS and those without PS. Initial analysis compared total numbers in each group, their gender and type of admission (elective or emergency). We then investigated the changing numbers and proportion of operations over time. The final analysis was based on comparisons according to the decade of birth to capture the influence of childhood socio-economic circumstances now recognised to have a major bearing on the risk of ulcer disease. Within each birth cohort we examined the numbers operated on, the changing proportions with PS, the gender and the mean age at operation.

The dates of birth extend from 1868 to 1974. The numbers born before 1880 and after 1960 were sparse and spread beyond a decade, so have been excluded from birth cohort analysis. Nevertheless their numbers are provided as a footnote to Table 2 for completeness.

Statistical analysis

P values for categorical comparisons were calculated using Fisher's exact test (two-tailed). Changes in age at operation over time were analysed by linear regression of mean age at operation against mid-year of 10-year birth cohort for both the No-PS and PS groups. The slopes of the two regression lines were compared using grouped linear regression.⁴

Changing proportions of PS over time: worldwide data

To put our findings in perspective, we reviewed data from several original reports of ulcer series published around the world at any time during the 20th century

TABLE 1 All patients: Elective and emergency admissions and the pattern of complications

	No pyloric stenosis n=3697	Pyloric stenosis n=481	p
Overall (n=4178)			
Mean age (SD)	49.9 (14.1)	56.2 (14.2)	<0.001
Male sex*	2869/3676 (78%)	332/481 (69%)	<0.001
Emergency	804/3697 (22%)	133/481 (28%)	0.004
Pattern of emergency admission: (n=937)			
Without bleed/perforation	143/804 (18%)	82/133 (62%)	<0.001
With bleed/perforation	661/804 (82%)	51/133 (38%)	
Type of complication (n=712)			
Bleed	505/661 (76%)	42/51 (82%)	0.49
Perforation	149/661 (23%)	9/51 (18%)	
Bleed and perforation	7/661 (1%)	0/51 (0%)	-

*Gender not known in 21, all No-PS

and from which the proportion with PS in PUD could be calculated. The reports were identified by a PubMed search, limited to those written in English, with full copies available either through PubMed or through libraries at the University of Sheffield and Rotherham Hospital. We did not employ formal systematic review methodology for this process. We categorised the data from country or continent of origin and subdivided into surgical and non-surgical series; the latter included series based on autopsy, hospital inpatients and outpatients and, more recently, endoscopy. Each result is presented as the proportion with PS and displayed at the mid-point of their respective survey period.

RESULTS

143 patients were excluded because of incomplete data or transfer from other hospitals; 62 patients were excluded as they had undergone non-definitive emergency operations. Our analysis therefore includes data on 4178 patients who had operations for PUD, and within this figure, 481 patients (11.5%) who met our definition of PS. Of all 4178 individuals, 2208 had vagotomy operations and variations (PS: n=325, 15%), 1881 had partial or total gastrectomy (PS: n=122, 6%), and 89 had gastroenterostomy alone (PS: n=34, 38%).

Gender

Gender was not recorded in 21 patients (all in the No-PS group), but Table 1 shows that men comprised the majority of both operation groups. The proportion of PS amongst men was significantly lower than amongst women (332/3201 [10.4%] vs. 149/956 [15.6%]; $p < 0.001$).

Pattern of admissions

937/4178 (22.4%) patients underwent emergency operations, with a slightly higher proportion in the PS

group (133/481; 28%, $p=0.004$). Emergency admission was mainly for haemorrhage or perforation in the No-PS group but more for other reasons in those with PS, such as severe vomiting (Table 1).

Both PS and haemorrhage or perforation occurred in 51/133 (38%) of emergency admissions in the PS group. We were unable to distinguish the prime indication for emergency admission from the database. For example, a patient may have been admitted for haemorrhage or perforation and at operation noted to have PS, whether previously known or now newly recognised. Conversely an emergency admission for PS-related symptoms may have been further complicated by haemorrhage or perforation.

Figure 1 shows the annual number of operations for the two groups. No-PS operation numbers fluctuated, sometimes markedly, from year to year. From its peak in 1944 the numbers fell sharply until 1959 and then rose erratically to a new peak in 1972. The numbers with PS also fluctuated but with a different trajectory, rising to a peak in 1974. From these points onwards the numbers fell irreversibly, i.e. before the first full year of effective medical treatment (1977).

The influence of decade of birth

We present the data of the eight birth cohorts, each a 10-year period between 1880 and 1959, comprising No-PS n=3583 and PS n=468 (Figure 2). Details of those excluded from analysis are shown as a footnote to Table 2. The proportion of patients with PS fell in successive birth cohorts, more steeply in the last. The fall is more striking in women, fewer in absolute numbers yet with a higher proportion with PS except in the final cohort which comprised only 10 women, all without PS (Figure 2).

TABLE 2 Birth cohort: Operation numbers, gender and age

	1880-89	1890-99	1900-09	1910-19	1920-29	1930-39	1940-49	1950-59
All patients (n)								
No-PS	176	513	928	768	629	322	179	68
PS	36	83	132	100	71	29	15	2
Men (n)								
No-PS	130	408	721	599	465	251	149	58
PS	23	54	96	71	46	17	11	2
Women (n)								
No-PS	41	98	202	165	164	71	30	10
PS	13	29	36	29	25	12	4	0
Mean age at operation (years)								
No-PS	65.3	59.6	53.6	49.7	45.2	38.7	33.3	27.9
PS	74.0	65.3	59.6	52.9	47.5	40.6	34.2	30.3
Mean age difference, PS vs no-PS (yrs)	8.7	5.7	6	3.2	2.3	1.9	0.9	2.4

PS: Pyloric stenosis

Missing data

Date of birth: n= 81 patients (No-PS 76, PS 5); excluded from birth cohort analysis.

Gender: n=21 all No-PS; included in 'All patients' and 'mean age' but excluded from gender analysis.

Excluded from birth cohort analysis (owing to low numbers, see Methods):

Cohort born 1860-69: No-PS n=1, PS n=0; 1870-79: 19 and 4; 1960-69: 15 and 4; 1970-79: 3 and 0 respectively.

Table 2 shows that operation numbers for both No-PS and PS peaked in the third birth cohort (1900–1909) then declined successively in both groups, but more so in PS. Numbers with No-PS fell 13.6 fold (to 7.3% of peak), but by 66-fold in PS (to 1.5% of peak). Finally, Table 2 shows that mean age at operation declined in both groups, but at significantly different rates (regression slope for No-PS vs. PS = -0.527 vs. -0.624; $p=0.0004$ for comparison), i.e. the PS group declined more steeply. PS subjects were older throughout, the age gap narrowing towards the end.

The worldwide picture (Reference list available in online Appendix)

Figure 3 shows the proportions with PS reported in 58 studies collected from different parts of the world, varying widely by geographical location, period of survey and the series type, i.e. surgical or non-surgical. The data from the UK (1901–1988)^{A1–A11} show a clear decline in PS from the beginning of the 20th century, the pattern broadly similar to that in the USA starting a little later (1922–2006).^{A12–A25} Data from India (1932–1989)^{A26–A35} reveal a higher proportion early in the series making the decline more striking as it fell to levels approaching those seen more recently in the West. Such a sharp decline is well exemplified by the large sequential studies from Madanagopalan et al. in Chennai (formerly Madras) who, in two separate series, each of 1200 patients, noted that the proportion with PS fell from

51% in 1942–45 to 31% in 1962–66.^{A29}

A similar (but variable) pattern of low and/or declining incidence of PS is to be seen in the Far East in reports from Singapore (14.4%, 1949–60)^{A36} and Hong Kong (3.8%, 1976).^{A37} This was particularly so in Taiwan where a decline was seen in two sequential series: from 9% (1951–80) to 2% (1981–1990)^{A38} and from 21% (1982–84) to 9.8% (1991–92).^{A39} The exception however is in Japan where the proportion rose from 5.8% (31/537) in 1973–81 before H2RA to 10.7% (39/365) in 1982–1991 since their introduction.^{A40} Data from Africa start much later (1967–2001),^{A40–A55} and show a rising trend of PS in the non-surgical series. In contrast the proportions in the surgical series show marked variability with a mean value of 45%.

DISCUSSION

The decline in PS

Our results show a sustained decline almost to the point of disappearance in both the numbers of operations for definitive ulcer surgery and in the subset with PS. H2RA and later PPI drugs would have played a major, albeit difficult to quantify, role in this decline towards the end of the study. Yet these drugs which revolutionised PUD treatment cannot be the full explanation, for although the precise start of the decline is difficult to define, the

trend was apparent even before their introduction. We have previously reported a similar decline in the numbers of elective operations for PUD, prior to H2RA, within Trent Regional Health Authority (population 4.6 million).¹ These data suggest that the natural history of PUD had started to change before modern drug treatment, signifying the influence of other environmental or secular factors. Our results contrast with the growth in the population of York over the study period; census data from 1921 to 1991 show a steady growth of the city population rising from 106,278 to 172,847.⁵ The hospital catchment area however is much larger, currently about 350,000 but we do not have reliable figures for the earlier periods. Ethnic minorities comprised 2.2% in the 2001 census, the only data available.⁶

Susser and Stein observed that mortality from PUD fell steadily in successive cohorts born between 1820 and 1940 prompting their 'birth cohort hypothesis', elegantly defined as 'each generation has carried its own particular risk of bearing ulcers throughout adult life'.⁷

PUD is also related to social class, the poorest having the highest risk.^{8,9} This link became clearer with the identification of *Helicobacter pylori*,¹⁰ arguably the major causative factor of PUD. It is now recognised that those deprived in childhood (for example living with poor sanitation or family overcrowding) have the highest *H. pylori* infection risk.¹¹⁻¹⁶ As socio-economic conditions improved in Western societies in the 20th century, so too the prevalence and mortality of PUD declined, with changes related to the period of birth.¹⁷⁻²⁰ The declining numbers of operations observed in York in successive decades suggests this too is a birth cohort effect.

Birth cohorts and the York study population

The concept of the birth cohort effect as it applies to our data becomes more tangible when the major socio-economic changes in York during the early 20th century are considered. Construction of the first proper sewage disposal system began in the 1890s but, interrupted by the First World War, it was not until the mid-1920s that all houses were connected.²¹ Extensive slum clearance in the 1920s and 1930s further improved living conditions. It is possible that these changes in hygiene and lifestyle may have impacted on rates of PS. However, the effect of the period of birth alone would be expected to influence No-PS and PS groups equally, resulting in a parallel decline in operation numbers. In fact there was a more rapid reduction in the proportion of PS patients in successive cohorts. Two possibilities arise; the birth cohort effect might be disproportionately greater in subjects who may in earlier years have progressed to PS. The other possibility is that some unknown factor might be

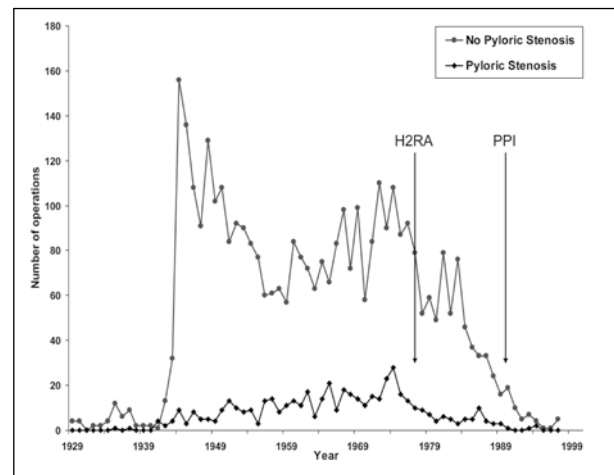


FIGURE 1 Total numbers of operations per year 1929-1997, subdivided into those with pyloric stenosis and those without pyloric stenosis. The arrows indicate when modern medical treatment was introduced in the UK, i.e. H2-receptor antagonists and proton pump inhibitors

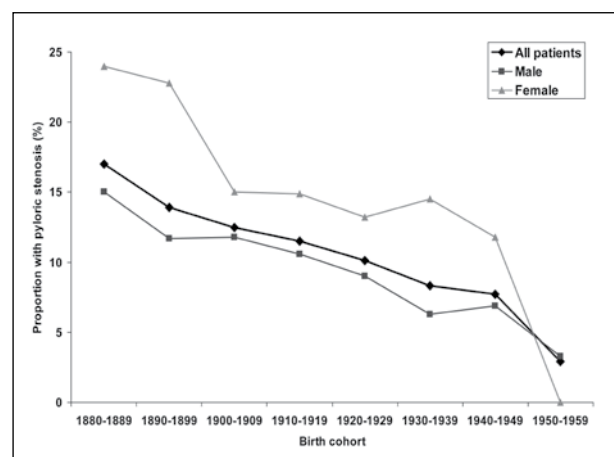


FIGURE 2 Analysis by birth cohort: The data show the proportions with pyloric stenosis in successive 10-yearly bands grouped by decade of birth, and subdivided by gender. Missing data: See footnote to Table 1

operating which we speculate may be related to the changing nature of fibrosis as discussed below. Unexplained, however, is the selective and steeper decline of mean age in the PS group.

Data quality and limitations

Our results and conclusions are influenced by the definition of PS used and by the quality of our data.

Definition of PS: The clinical course of PS is varied, recognisable but more difficult to define. We therefore based our definition strictly on operative findings which has the advantage of a firm diagnosis consistently applied.

Accuracy of data: We had complete information on the date of operation and the procedure from which we

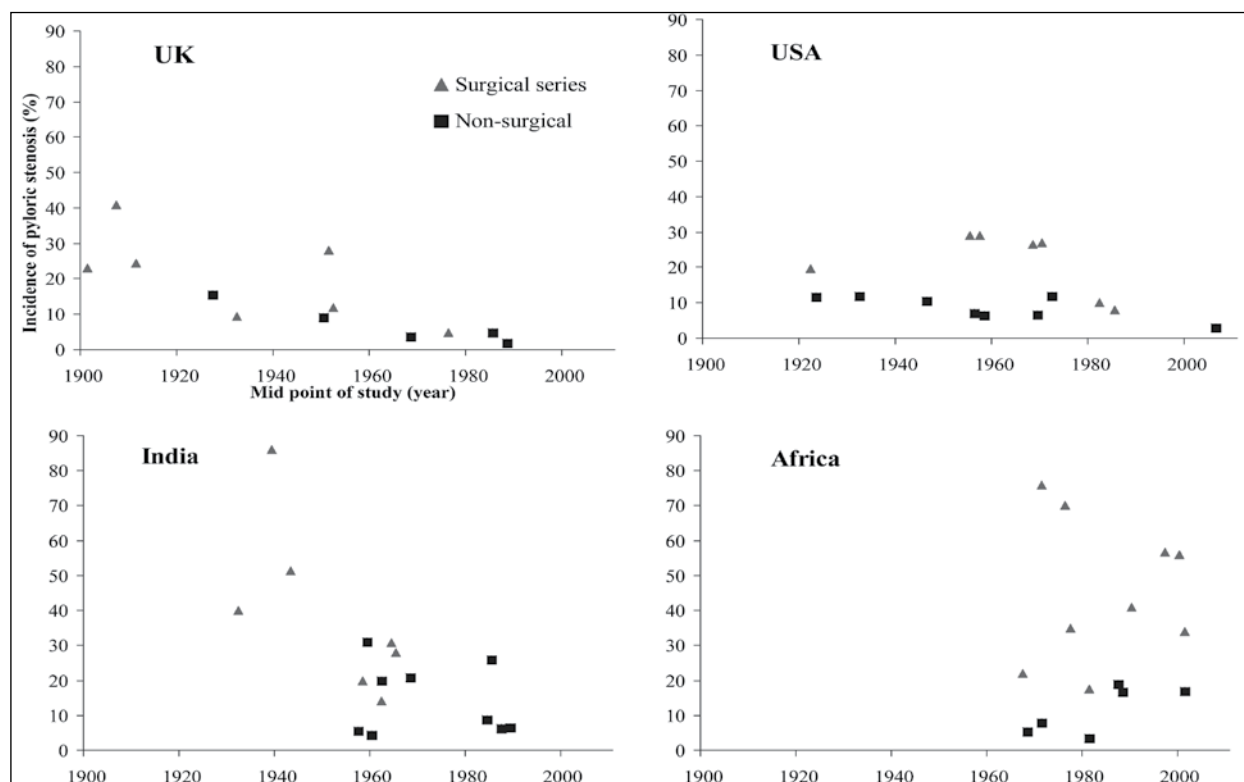


FIGURE 3 World data: the proportion of pyloric stenosis reported from different parts of the world through the 20th century. Each data point represents the mid-point of the study period

could infer whether it was done with intent to 'cure' (e.g. partial gastrectomy, vagotomy and drainage) which we included in the study, or only as a temporary measure which we excluded. We also had the date of birth in >98% of all patients. These data formed the basis of the analysis, and have the advantage of completeness and consistency of coding over many decades. This is a key strength of our analysis - data were recorded consistently, systematically and for long periods, reflecting the interest shared by generations of York surgeons. Such data are likely to be more complete than from centres without this specific interest. Re-examination of every record (see Methods) by a single experienced surgeon (RH) strengthened the quality and uniformity of our data.

Limitations: There are limitations to our data however. Being from a single centre our data are prone to be disproportionately affected by local circumstances. For example, operation numbers would fall if a surgeon was away for long periods or increase during periods of surgical enthusiasm, such as recruitment into clinical trials. While the key data were consistently recorded, the depth of detail noted (e.g. extent of fibrosis or adhesions) varied, reflecting different surgeons' inputs and the difficulty of sustaining detailed recording over many years. We have therefore restricted our analysis only to whether PS was present or not.

Our patients, being at the severe end of the spectrum, cannot represent the full pattern of ulcer disease as a whole in the York population, nor the full clinical span of pyloric obstruction as those with milder problems would not come to operation. Being a surgical series, the York database does not contain information on PS managed with endoscopic balloon dilatation. This approach however could not have contributed to the observed reduction in PS as the method was introduced only after the end of the study period. The Rotherham peptic ulcer database provides supportive evidence: it includes all patients treated medically and surgically and overlaps the last two decades of the York data. It too shows a similar decline in PS, the numbers seen (in 5-yearly periods) falling from 44 (1981-85) to 15 (1996-2000).²²

The changing pattern of PS worldwide

The proportion of PUD patients with PS has changed across many countries during the course of the 20th century. However, comparison between individual studies is not straightforward, a problem well summarised by Ellis in 1966: 'Figures vary with the criteria accepted for the diagnosis of PS and with the particular sample considered since they may be based on autopsy or surgical series, or on the general hospital population, or on the PUD population as a whole'.²³ To these criteria we can add variation caused by modern medical therapy and advances in endoscopic treatment, specifically

balloon dilatation. The decline of PUD in the West correlates well with improvements in socio-economic conditions resulting in the declining prevalence of *H. pylori* infection. The major complex changes leading to improvement in public health took place much earlier in the UK and USA than in India where the prevalence of PUD is now known to have also decreased.²⁴ *H. pylori* infection rates however remain high in developing nations.^{12,25,26} We suggest that as increasing numbers in Africa benefit from improving socio-economic circumstances a similar decline in PUD and of PS may, in time, occur there too.

WHY HAS PS DECLINED?

Declining ulcer prevalence

Although less frequent now, PUD continues in the West but PS has largely disappeared. Each of the following could explain one aspect of the changing picture: first, as the prevalence of *H. pylori* falls, fewer people develop PUD, hence fewer go on to develop PS, the reduction being proportionate; second, a selective decrease in the number developing pylorus-related ulcers would lead to a disproportionate reduction in PS. A third possibility is that irrespective of any change in the frequency of PUD, a spontaneous attenuation of excessive fibrosis would itself result in fewer people with gastric outlet obstruction; however it would not alter the total numbers with PUD.

To explain the observed reduction in PUD but with a disproportionate fall in PS we suggest two of the above independent risk factors have acted together, namely, a declining risk of PUD and as described below, a separate decreasing risk of developing excessive fibrosis in those who would otherwise have gone on to develop PS.

Selective attenuation of fibrosis?

The prevalence of PUD and its associated mortality has declined in the West.¹⁷⁻²⁰ We are unable to find evidence of a selective reduction of pyloric ulcers but, noting the changing descriptions of operation findings during the 20th century, we were persuaded that a selective reduction in excessive fibrosis, characteristic of PS, is possible.

The early surgical literature, for example Moynihan's classical surgical series²⁷⁻³¹ spanning 1900–1923, gives vivid descriptions of florid fibrosis in association with both gastric and duodenal ulcers, resulting in marked narrowing causing both the 'hour-glass stomach' and PS. Strikingly the fibrosis was often widespread over the stomach and associated with adhesions spreading to the liver and diaphragm. Haubrich, in the USA, on reviewing two of his own surgical studies (1953 and 1961) on refractory ulcer disease, noted that the majority had

penetrating ulcers against which there had been a vigorous fibrotic response resulting in adhesions in up to one-third of the patients.³² Such patients had been operated on when the medical treatment then available, often given over prolonged periods, had failed to relieve. Two decades later, in the early days of modern therapy, we defined H2RA-refractory ulcer as failure to heal within three months on standard or high dose treatment. In sharp contrast to the earlier descriptions and against expectations, the Rotherham H2RA-refractory ulcer patients operated on rarely showed fibrotic changes and none had PS.³³

Ulcer complications: a conceptual model

The reduction in fibrosis and PS over time is in striking contrast to haemorrhage and perforation, the other ulcer complications, which continue to cause major clinical problems.^{1,2} As a conceptual model to accommodate the opposing patterns we suggest haemorrhage and perforation represent the failure of an appropriate and timely fibrotic defence, whereas PS is the consequence of disproportionate fibrotic over-reaction. For the reasons stated earlier, it therefore seems possible that selective attenuation of the once-excessive fibrosis may have contributed to the remarkable reduction in PS. These opposing trends would not explain why a small proportion with PS (11% in this series) also suffered bleeding or perforation. We therefore suggest that in some, 'impaired defence' may be more focal than generalised throughout the stomach and duodenum.

Pyloric stenosis: a distinct natural history?

The York data show two striking features which cannot be explained by the declining prevalence of ulcer disease alone: first, as discussed, the selective reduction in the proportions with PS across the birth cohorts irrespective of the total numbers of operations; second, the selective and steeper decline of mean age in the PS group. Together these observations suggest patients with PUD who would have gone on to develop PS have a different natural history from the outset which becomes apparent only over time.

CONCLUSION

With steadily improving socio-economic conditions in successive birth cohorts, the numbers coming to surgery for PUD and PS have steadily declined but with a disproportionate reduction in the PS subgroup. Taken together with the indirect evidence favouring spontaneous attenuation of excessive fibrosis, these changes which began before modern medical treatment suggest a changing natural history of PUD, its effect greatest on those who would have gone on to develop PS. While the decline in PUD is well recognised, the selective and marked fall in PS is not. We believe this is the first time

the decline of PS throughout the 20th century has been documented and linked to the birth cohort effect.

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Dedication

As a mark of admiration and respect the authors dedicate this report to Arthur HC Visick, the 'Gastric Visitors' the late Mary Dent and Sheila Dickson, and the supporting staff of the York Peptic Ulcer Research Trust.

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