Radiological progression of end colostomy trephine diameter and area

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Background: Development of a parastomal hernia is common following abdominoperineal excision (APE). The true incidence is difficult to assess fully owing to differing lengths of follow-up and techniques used to assess herniation; radiological or clinical. The primary aim of this study was to evaluate colostomy diameter by studying the rate of change of axial and sagittal trephine diameters, trephine area, and the ratio of the trephine over time. A secondary aim was to investigate variation in trephine area and variables affecting parasternal hernia over time.

Methods: Serial CT scans performed after APE from January 2006 to December 2014 were reviewed. Variables analysed included age, sex, trephine position relative to rectus abdominis muscle (RAM), type of incision for stoma creation, and axial and sagittal trephine diameters measured on follow-up CT. A Bayesian hierarchical modelling framework was used to examine the relationship of trephine diameters, area and ratio over time.

Results: Of 112 patients undergoing APE, 103 were eligible for analysis; this included 91 colostomies (88·3 per cent) through the RAM and 12 (11·7 per cent) lateral to the RAM. Median age of the patients was 68 years. Sixty patients (58·3 per cent) had a circular and 43 (41·7 per cent) a cruciate incision for stoma creation. The sagittal trephine diameter increased by 0·22 (95 per cent credible interval 0·12 to 0·32) mm/month for both sexes. Women reported a significant increase in axial trephine diameters; the male : female ratio difference was −0·17 (−0·30 to −0·03) mm/month and for trephine areas −6·21 (0·96 to 13·7) mm²/month. Patient age, colostomy trephine location and shape of incision were not statistically significant variables for parasternal hernia.

Conclusion: Female sex was the only variable affecting the rate of increase in axial trephine diameter and trephine area over time.

Introduction

A parastomal hernia is defined[1] as 'a protrusion of abdominal contents through the trephine of the abdominal wall by which a stoma was formed' and is reported to have an incidence of 4–48 per cent. It is one of the most frequent complications following stoma formation[2,3]. Patients with a parastomal hernia may develop abdominal pain, lack of appliance security, faecal leakage and skin irritation, all of which can negatively affect their quality of life[4]. A number

of surgical strategies have been developed to prevent and treat parastomal hernias, although high recurrence rates remain an issue[5].

The size of the defect created in the abdominal wall may influence the development of parastomal hernia[3,6]. This defect is referred as the trephine. Previous work[6] has suggested that for every millimetre increase in trephine size, there is a 10 per cent increased risk of parastomal hernia development. It was proposed[7] that the trephine diameter should be no greater than 4·0 cm.

a Axial trephine diameter   **b** Sagittal trephine diameter
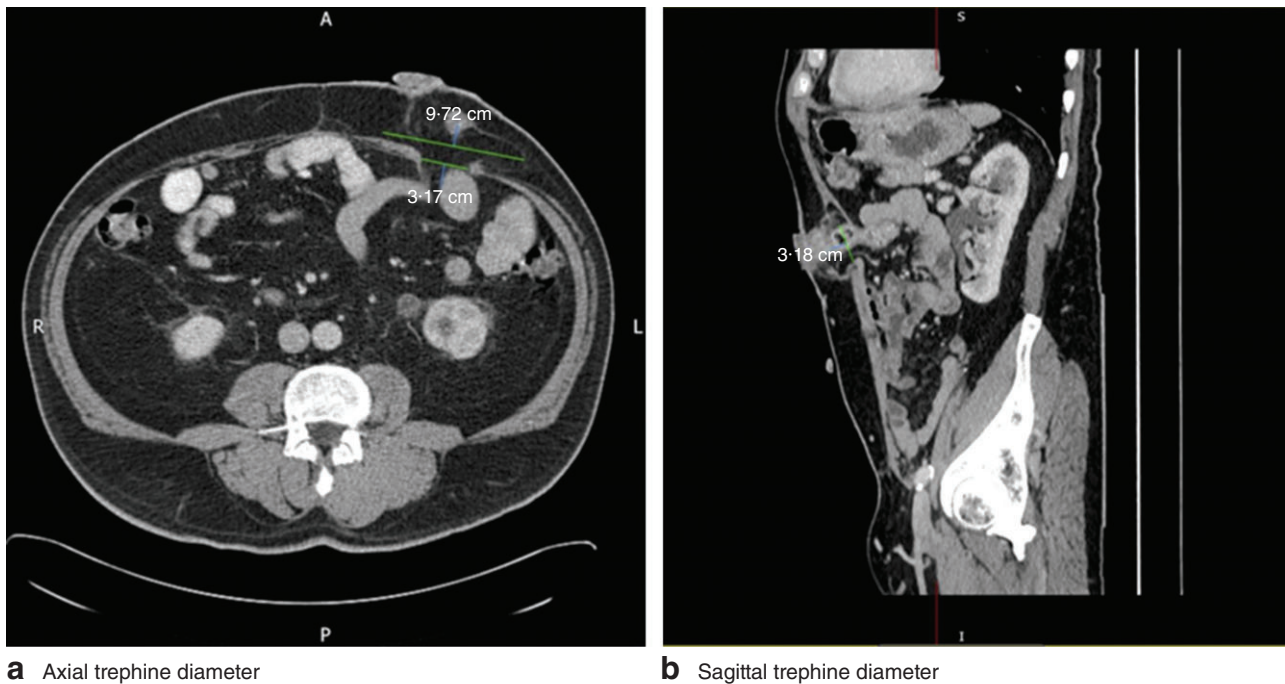
Fig. 1 Postoperative CT scan from a single patient: **a** axial trephine diameter measurement (3·17 cm) and hernial sac (9·72 cm); **b** sagittal trephine diameter measurement (3·18 cm). Trephine area was approximated as: Area = π(A/2)(B/2), where A represents sagittal diameter and B represents axial diameter

The primary aim of this study was to evaluate the progression of the colostomy trephine size by studying the change of both the axial and the sagittal trephine diameter, the area of the trephine, and the ratio between these diameters over time. A secondary aim was to investigate the changes in trephine area and variables affecting parastomal hernia development over time, including age, sex, colostomy position relative to the rectus abdominis muscle (RAM) and shape of incision during stoma formation.

Methods

This study reported in accordance with the STROBE guidelines[8] and European Hernia Society recommendations[9].
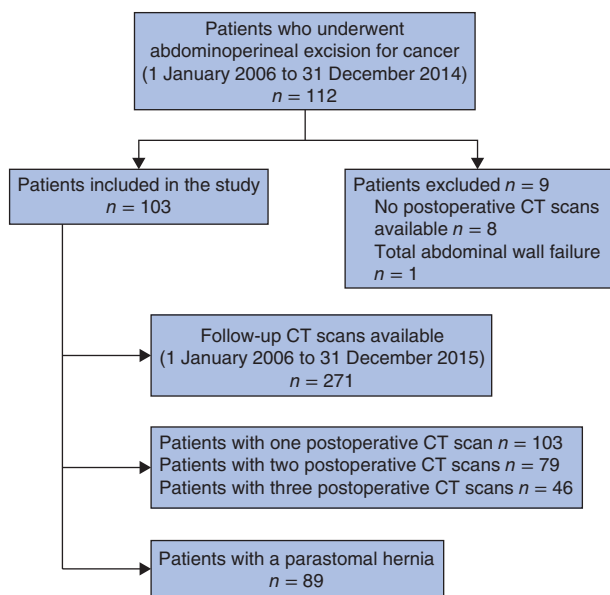
Study design

A review was conducted of all end colostomies performed between 1 January 2006 and 31 December 2014 after elective abdominoperineal excision (APE) for cancer at the Royal Devon and Exeter Hospital, a large general hospital with a referral base of 320–340 colorectal cancers per year.

The stoma site was marked before surgery with consideration of previous surgery, skin folds, body shape and position of clothing. Age at operation, sex, curative intent, colostomy position relative to the RAM and shape of the incision (circular *versus* cruciate) made during stoma formation were recorded and inserted into a Microsoft Excel® database (Microsoft, Redmond, Washington, USA). Initial trephine shape and size (not recorded) were created by surgeons according to their own preference. For laparoscopic surgery, stomas were created while the abdomen was insufflated.

CT was performed routinely according to clinical need and colorectal cancer follow-up guidelines[10]. All postoperative CT scans for every patient up to December 2015 were reviewed. Patients with no postoperative CT scan were excluded, along with all CT scans performed after parastomal hernia repair. Position of the colostomy was assessed via CT on an InSight PACS (picture archiving and communication system) workstation (Insignia Medical Systems, Basingstoke, UK). The size of the trephine was measured using CT reconstruction, taking the maximum diameter of the defect in the abdominal wall at the musculofascial layer of rectus sheath.

Formal ethical approval was not required owing to the retrospective nature of the study, although all patients had consented to surgical treatment and CT.

Patients who underwent
abdominoperineal excision for cancer
(1 January 2006 to 31 December 2014)
n = 112

Patients included in the study
n = 103

Patients excluded *n* = 9
  No postoperative CT scans
  available *n* = 8
  Total abdominal wall failure
  n = 1

Follow-up CT scans available
(1 January 2006 to 31 December 2015)
n = 271

Patients with one postoperative CT scan *n* = 103
Patients with two postoperative CT scans *n* = 79
Patients with three postoperative CT scans *n* = 46

Patients with a parastomal hernia
n = 89

Fig. 2 Patient flow diagram for a retrospective study on the radiological progression of permanent end colostomy trephine diameter and area over time

Classification of parasternal hernia

The Moreno-Matias (MM) classification system and the European Hernia Society (EHS) classification of parasternal hernia were used[11,12]. These radiological classification systems were used to classify all postoperative abdominal CT scans. The hernial sac diameter was also measured (*Fig. 1*).

Outcome measures

Axial and sagittal trephine diameters were determined by measuring the widest diameter in each plane using the measure tool on the InSight PACS (*Fig. 1*). Three diameters were taken for each scan in the axial and sagittal plane, and the medians of these measurements were used for the study. The area of the trephine was approximated as Area = π(A/2)(B/2), where A is the sagittal and B the axial diameter. The ratio of the trephine was calculated as A/B.

Statistical analysis

Statistical analysis was performed using R version 3.1.2 statistical programming language (R Foundation for Statistical Computing, Vienna, Austria). A Bayesian hierarchical modelling framework was used to examine the relationship of trephine diameters (axial and sagittal), area and ratio, with time since surgery for all patients. The effect of age (at surgery), sex, colostomy position (relative to RAM)

Table 1 Patient characteristics

|	No. of patients (*n* = 103)
Age at operation (years)*	68 (26–86)
Sex ratio (M : F)	44 : 59
Dukes' class or type of tumour	
A	41 (30·8)
B	39 (37·9)
C	20 (19·4)
Adenoma	2 (1·9)
Anal SCC	1 (1·0)
Type of surgery	
Laparoscopic	24 (23·3)
Open	79 (76·7)
Position of stoma	
RAM	91 (88·3)
LRAM	12 (11·7)
Shape of trephine	
Circular	60 (58·3)
Cruciate	43 (41·7)
Time to earliest CT scan after surgery (months)*	9 (0–43)†
Time from first to second CT scan (months)*	11 (0–39)†
Time from second to third CT scan (months)*	11 (2–37)
Trephine diameter on earliest CT scan (mm)*	
Axial	20 (6–47)
Sagittal	28 (11–62)
Duration of CT imaging period (months)*	24 (0–92)†

Values in parentheses are percentages unless indicated otherwise; *values are median (range). †0 months indicates less than 30 days from the date of surgery. SCC, squamous cell carcinoma; RAM, rectus abdominis muscle; LRAM, lateral to rectus abdominis muscle.

and trephine shape (during stoma formation) on rate of trephine progression was allowed for. Specifically, the formulation of the model considered is:

$$y_i(t) \sim N\left(\mu_i(t), \sigma^2\right) \quad \mu_i(t) = \alpha_i + \beta_i t + \gamma_A Age_i t$$
$$+ \gamma_G Gender_i + \gamma_{St} Stoma_i + \gamma_{Sb} Shape_i$$

where $y_i(t)$ is a size measurement: either the sagittal diameter, the axial diameter or the area of the trephine for patient i, in month t after surgery. A slightly different formulation was used for the ratio of sagittal to axial; see *Appendix S1* (supporting information) for full details of both models. The variable Age_i was centred at the mean age of the sample, so that it was negative/positive if the age of patient i was below/above the mean age. The variable $Gender_i$ was zero if patient i was male and one if female; $Stoma_i$ was zero if the stoma was edge and one if rectus; and $Shape_i$ was zero if the shape was circular and one if cruciate.

The model assumed that $y_i(t)$ has a Gaussian distribution, with mean $\mu_i(t)$ and variance σ^2, that quantified measurement error. At time of surgery ($t = 0$), the mean size for patient i was α_i. Then for $t > 0$, β_i was the monthly rate of change of size for patient i of mean age, male, with an edge stoma and circular shape. Thus, the parameters $\gamma_A, \gamma_G, \gamma_{St}$
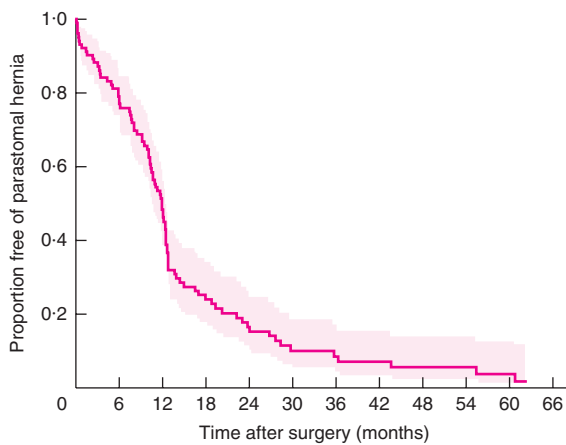
Fig. 3 Kaplan–Meier analysis of the estimated incidence of parastomal hernia in 103 patients according to the European Hernia Society classification of parastomal hernia. Approximate 95 per cent confidence intervals have been added to represent sampling uncertainty (as described by Kalbfleisch and Prentice[14])

Table 2 Comparison of parastomal hernia classification systems for the 103 patients

European Hernia Society classification	Moreno-Matias classification					
	0	1A	1B	2	3	Total
0	14					14
1	0	23	9	20	17	69
2		3		5	8	16
3					3	3
4					1	1
Total	14	26	9	25	29	103

and γ_{Sb} quantified the effect on the rate of change from the four associated variables.

The model described above was implemented in a Bayesian framework; unknown quantities were estimated using Markov chain Monte Carlo (MCMC). In this framework, parameters are treated as random variables whose 'prior' distribution expresses the uncertainty about their value before any data are observed. Prior distributions (priors) are combined with the observed data through Bayes' theorem to produce the posterior distributions for each parameter (posteriors). The posteriors express the uncertainty about model parameters after data have been observed, and all statistical inference is based solely on the posteriors. Here, the prior distributions used were as uninformative as possible, in order to allow the information in the data to determine the unknown quantities, such as the effects from the risk factors. MCMC is a numerical technique that produces samples of values that
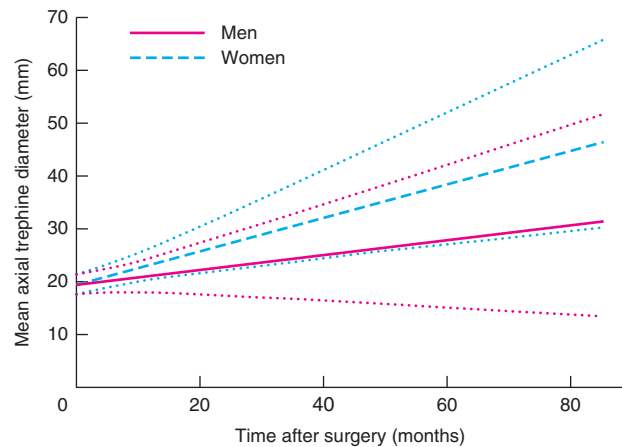
Fig. 4 Change in mean axial trephine diameter in men and women over time after surgery. The curves reflect people aged 65 years (the mean in the sample) who had a colostomy positioned lateral to the rectus abdominis muscle (age, stoma position and shape of trephine incision during colostomy formation were not significant in the model). Means are shown with 95 per cent credible intervals. The difference in trephine diameter in men compared with women was −0·17 (95 per cent credible interval −0·30 to −0·03) mm/month (P = 0·008)

eventually converge (after a certain 'burn-in' number) to samples of values from the posterior (distribution) of each parameter.

The equivalent of testing significance of various factors is to construct a 95 per cent credible interval (CrI) for the associated parameter (for example γ_G for gender/sex). The 95 per cent CrI expresses a range of values for γ_G inside which the true value of γ_G lies with probability 0·95. If zero lies within the 95 per cent CrI, then it can be claimed that there is not enough evidence in the data to support the hypothesis that the effect of the factor is not zero. Unlike confidence intervals, whose definition relies upon conceptual repetition of the observation process, CrIs intuitively express the range of values within which the true parameter value lies with probability 0·95[13]. In addition, for positive/negative significant estimates, the posterior probability p, that the estimate is less/greater than zero, can also be calculated to reflect classical P values (*Appendix S1*, supporting information).

Estimation of parasternal hernia-free survival was completed according to the Kaplan–Meier method.

Results

Of 112 elective APEs performed between February 2006 and November 2014 by three consultant surgeons, nine patients were excluded because of incomplete data (8
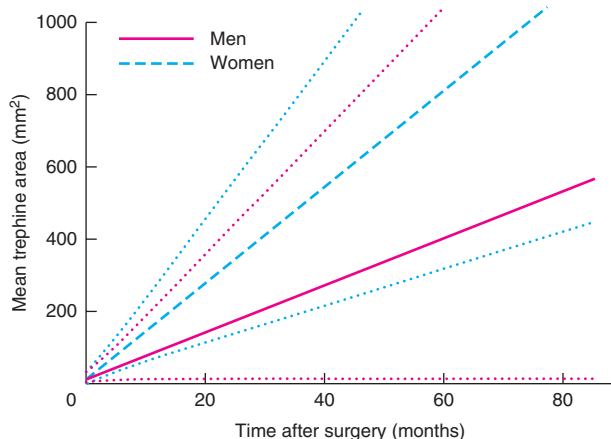
Fig. 5 Change in mean axial trephine area in men and women over time after surgery. The lines reflect people aged 65 years (the mean in the sample) who had a colostomy positioned lateral to the rectus abdominis muscle (age, stoma position and shape of trephine incision during colostomy formation were not significant in the model). Means are shown with 95 per cent credible intervals. The difference in trephine area in men compared with women was −6·21 (95 per cent credible interval 0·96 to 13·70) mm^2/month ($P = 0·009$)

patients) or total abdominal wall failure (1 patient) (*Fig. 2*). The remaining 103 patients were analysed. The median age of patients was 68·0 (range 26·0–86·0) years; the male : female ratio was 1·34 (*Table 1*). Some 271 CT scans were available in the postoperative follow-up period, from October 2006 to December 2015 (*Fig. 2*). The median number of scans per patient was 2·0 (range 1·0–9·0). Nine patients had mesh inserted during stoma formation: seven received porcine collagen (Permacol™; Medtronic, New Haven, Connecticut, USA) and two had synthetic mesh (Parietex™; Medtronic). Laparoscopic surgery was performed in 23·3 per cent of patients (24 of 103). Median time intervals between surgery and CT are shown in *Table 1*.

Rate of parasternal hernia

The rate of parasternal hernia at any time point was 86·4 per cent (89 of 103) according to the European Hernia Society classification. Kaplan–Meier analysis of patients with the endpoint of parasternal hernia is shown in *Fig. 3*.

When MM and EHS classifications were compared, the two systems showed good agreement for low grades of parasternal hernia. However, the MM classification documented a prevalence of more severe parasternal hernia compared with the EHS classification (*Table 2*).

Variation of trephine area and variables affecting parasternal hernia over time

The median axial trephine diameter on earliest CT imaging was 20 (range 6–47) mm (*Table 1*). The axial trephine diameter in men increased by a mean of 0·11 mm/month (95% CrI−0·07, 0·36), whereas in females it was a mean of 0·28 (95 per cent CrI 0·1 to 0·45) mm/month. The difference between axial trephine diameter in men compared with women was −0·17 (−0·30 to −0·03) mm/month ($P = 0·008$) (*Fig. 4*). The effects of age, colostomy position (with respect to RAM) and shape of incision (during stoma formation) were not statistically significant.

The median sagittal trephine diameter was 28·0 (range 11–62) mm at initial assessment on the primary CT scan (*Table 1*). The sagittal trephine diameter increased overall by a mean of 0·22 (95 per cent CrI 0·12 to 0·32) mm/month ($P = 0·003$). There were, however, no significant differences between age, sex, colostomy position and shape of incision (cruciate or circular).

The mean area of trephine increased significantly over time: 13·46 (95 per cent CrI 5·03 to 22·00) mm^2/month in women ($P < 0·001$) and 7·24 (−3·73 to 17·94) mm^2/month in men ($P = 0·086$). Women had a significantly greater mean rate of increase compared with men. The difference between trephine area in men compared with women was −6·21 (0·96 to 13·70) mm^2/month ($P = 0·009$) (*Fig. 5*).

There were no significant differences between ratio of the trephine and age, sex, colostomy position or trephine shape (data not shown).

Discussion

This study has demonstrated that trephine size increased over time in both axial and sagittal planes, increasing the overall area of the trephine. As the trephine size increased, the risk of parasternal hernia also increased; this may explain the high incidence of parasternal hernia in the study. In the present study, parasternal hernias were classified radiologically, unlike many previous studies[2−4] based on symptoms and clinical examination, and this may further explain the high incidence of parasternal hernia. Radiological assessment indicated that sagittal trephine diameter increased at twice the rate of axial trephine diameter, implying a change in the shape of the trephine over time.

It has been advised[15] that the aperture created during initial surgery should only be wide enough to transmit a viable loop of bowel forming the stoma without causing ischaemia. It has also been suggested[16] that the majority of patients with a permanent end colostomy develop parasternal hernia within the first 2 years after surgery,

and that parasternal hernias are unlikely to develop with a trephine diameter of 25 mm or less, provided this does not enlarge with time. The present study contradicts these findings, as all trephine defects increased with time despite the median axial trephine diameter on earliest CT imaging being 20 mm.

A limitation of the present study was that nine patients had mesh implanted during stoma creation. This may have modified the rate at which a parasternal hernia developed. Given the nature of this study, trephine diameter was not measured at surgery. This will be studied further as part of the prospective National Institute for Health Research (NIHR) UK Cohort study to Investigate the prevention of Parastomal HERnia (CIPHER)[17]. CT was used according to clinical need, with varied time points after surgery for each patient.

Factors recognized as probable risk factors for parasternal hernia include female sex, aperture size, age (over 60 years), BMI above 25 kg/m^2 and hypertension[18,19]. This study did not find a significant relationship between age and trephine diameter progression, although it did demonstrate a significant sex difference, with faster trephine diameter progression in women. Women have a thinner RAM and thicker subcutaneous fat than men regardless of age[20]; these anatomical differences may contribute to a greater increase in trephine size and vulnerability to development of a parasternal hernia. It might also be the case that women may have had a larger trephine size at the beginning due to a greater depth of subcutaneous fat.

The site of stoma formation in relation to the RAM has been debated widely, with contradictory findings regarding the parasternal hernia development[21–26]. The present study found no significant difference in the rate of trephine size progression between colostomies created through the RAM or lateral to the rectus abdominis muscle (LRAM) after adjusting for age at surgery, sex and trephine shape. Colostomy position may not be as important as previously thought, although it is acknowledged that only 11·7 per cent of patients included for data analysis had a stoma created through the LRAM.

Similarly, although it has been suggested[18] that parasternal hernia development may be a result of surgical technique rather than stoma position, in the present series parasternal hernia developed regardless of the shape of incision.

Colostomy trephines increase over time regardless of age, sex, position and shape of incision, although at a faster rate in women. More research is needed to develop strategies to prevent parasternal hernia.

Disclosure

The authors declare no conflict of interest.

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Supporting information

Additional supporting information can be found online in the Supporting Information section at the end of the article.