BJR, 2024, **00**, 1–6
https://doi.org/10.1093/bjr/tqae167
Advance access publication: 2 September 2024
Research Article

Imaging findings in suspected penile fracture: alternative diagnoses and surgical correlation

Conrad von Stempel, MBBS*[,1,2], Alex Kirkham, MD[1], Axel Cayetano Alcaraz, MD[3], David Ralph, MBBS[3], Nim Christopher, MBBS[3], Asif Muneer, PhD[3], Pippa Sangster, MBBS[3], Hussain Alnajjar, MBBS[3], Chi-ying Li, MBBS[3,4], Miles Walkden, MBBS[1], Clare Allen, MBBCh[1], Doug Pendse, MD[1], Navin Ramachandran, MBBS[1], Dan Heffernan Ho, MBChB[1], Louise Dickinson, PhD[1], Rachel Hubbard, MBBS[1], Francesco Giganti, PhD[1,2], Wai Gin Lee, PhD[3]

[1]Department of Radiology, University College London Hospital, London NW12BU, United Kingdom
[2]Division of Surgery and Interventional Science, University College London, London WC1E 6BT, United Kingdom
[3]Department of Urology, University College London Hospital, London NW12BU, United Kingdom

*Corresponding author: Conrad von Stempel, MBBS, Department of Radiology, University College London Hospital, 235 Euston Road, London NW12BU, United Kingdom (conrad.stempel.21@ucl.ac.uk)

Abstract

Objectives: The primary objective is to compare the imaging and surgical findings in a cohort of patients with suspected penile fracture (PF).

Methods: Retrospective cohort study of all patients with suspected PF over an 11-year period at a tertiary referral andrology centre. All dedicated presurgical imaging with ultrasound (US) and MRI was analysed and correlated with intraoperative findings; alternative diagnoses were recorded.

Results: One hundred and ninety-three patients were included. One hundred and four (54%) had alternative diagnoses to PF including dorsal vein rupture and haematoma. Ninety-nine (51%) underwent surgical exploration of which 89 (46%) had PF. US correctly confirmed the presence and marked the site of fracture in 92% of cases. MRI was primarily used as a problem-solving tool (13 cases) and demonstrated a more extensive injury than US (12 cases). The reported size of tunical defect on imaging was a median of 7 mm (IQR 4-10) significantly smaller than on exploration (median 20 mm, IQR 10-30; $P < .0001$).

Conclusions: US has a high positive predictive value in the confirmation of PF. MRI improves the detection and characterizing the extent of injury. Imaging marking informs surgical incision but defect size is under appreciated on all imaging modalities.

Advances in knowledge: Penile imaging has a high positive predictive value to not only confirm the diagnosis of PF but to stage the extent of injury and mark the skin, which impacts the surgical technique. Alternative diagnoses to fracture are common and imaging could prevent unnecessary surgical exploration.

Keywords: penile fracture; ultrasound; MRI; dorsal vein rupture.

Introduction

Penile fracture (PF) is defined as a rupture of the tunical albuginea of one or both corpora cavernosa sustained during an erection. It is an uncommon diagnosis seen in 1 in 175 000 emergency admissions to hospital.[1] Historically, PF was diagnosed clinically with history and physical examination followed by surgical exploration. This approach, while accurate, led to a significant rate of negative exploration and the associated morbidity of a subcoronal incision with penile degloving.[2,3]

Modern diagnostic imaging has revolutionized all aspects of surgical care including the management of trauma. Blunt abdominal trauma is now safely triaged for nonoperative management by CT where previously, an exploratory laparotomy would have been undertaken.[4] Diagnostic imaging also has the potential to improve the management of penile trauma.

The most useful imaging modalities for penile trauma are ultrasound (US) and MRI. There are limited published data that suggests that penile imaging may identify alternative diagnoses and prevent unnecessary surgery.[2] The site of the suspected PF can be identified by US and marked on the skin.[5,6] Skin marking reportedly facilitates a targeted incision for surgical repair.[6-8]

This study aims to clarify the contemporary role of imaging for suspected PF and compare imaging and surgical findings in the largest cohort of patients to date. There is a need for such data to inform the formulation of future guidelines on the diagnosis and management of penile trauma with or without associated fracture.

Methods

We conducted a retrospective review of all patients presenting with acute trauma to the penis and a clinical suspicion of PF who underwent dedicated penile imaging performed between January 2010 and January 2022. All cases of surgical exploration for PF were identified from the institutional surgical database and correlated with radiological findings. Surgical operation notes were reviewed by either a

Received: 28 December 2023; **Revised:** 23 June 2024; **Accepted:** 19 August 2024

Consultant Uro-Andrologist or Senior Clinical Fellow (W.G. L. and A.C., respectively). All radiological requests for penile US and MRI performed in the study window were identified from the institutional electronic patient record system (Epic) using the search terms 'penile', 'penis', 'tunica', 'fracture', 'blunt' and/or 'trauma'. All imaging and reports were reviewed by an experienced Consultant genitourinary radiologist (C.v.S.).

Patients

All patients were referred to the Andrology service with suspected PF. Most developed pain and penile swelling during sexual intercourse but some also sustained blunt trauma to the erect penis (self-inflicted or otherwise). All patients were clinical assessed by a Senior Clinical Andrology Fellow and discussed with an Andrology consultant. Patients included in this study were all referred for imaging prior to consideration of surgical exploration as per departmental guidelines. Imaging by US and/or MRI was performed within 48 h of presentation in all cases. Surgery was indicated in cases of confirmed tunical rupture on imaging (US and or MRI) or in cases where despite imaging results being indeterminate or negative for PF, there remained a significant clinical concern for PF after clinical examination by an Andrology consultant.

Data collection

Variables recorded were demographics and mechanism of injury.

Operation notes were studied and confirmation of tunical defect, laterality and size of defect and whether the incision was guided by skin marking were recorded. Additional injuries to the corpus spongiosum and urethra and alternative diagnoses other than fracture were documented.

A comprehensive review of the images was performed and recorded the laterality of tunical defect, the size and position, and the presence of additional injuries including suspected corpus spongiosal and urethral injury. Alternative diagnoses to PF were also documented.

Imaging protocols

US studies were performed by a dedicated genitouroradiology senior fellow or consultant in all cases using a 12 or 18 MHz linear probe on an Acuson 500 or S2000 (Siemens, Germany). US was performed from crura in the perineum to the glans both ventrally and dorsally in axial and longitudinal planes. At the site of suspected tunical breach, calliper measurements were used to measure the tunical defect size. In select cases, where there was a history of haematuria and a suspected urethral injury, a 5-mL solution of air and agitated saline or microbubble contrast (Sonovue®, Bracco, Italy) was gently instilled into the urethra via a syringe placed in the meatus and simultaneous US was performed to identify urethral extravasation and confirm urethral rupture.

Unenhanced MRI scans were performed in the unstimulated state at 1.5 or 3 T (Avanto, Siemens or Achieva, Philips). Surface coils were used and T2 weighted (T2w) (Repetition Time (TR) 5 s; Echo time (TE) 2.5 s) images in orthogonal planes (axial, coronal, and sagittal) with small field of view (49.6×24cm) were obtained to cover the entire penis including crura and bulb.

Imaging definitions

PF was defined on imaging as a clear discontinuity/defect in the hyperechoic tunica on US, and/or low signal tunical defect on T1 and T2 imaging. A PF was always associated with a peritunical haematoma which 'mushrooms' out of the corpus cavernosum. The presence of a peritunical haematoma without definite tunical disruption was also identified and grouped separately (Figure 1).

Corpus spongiosal injury was diagnosed where oedema and/or disruption in the spongiosal membrane was seen on US or MRI. Urethral injury was suggested with the presence of a hypoechoic fluid collection suggestive of urine, adjacent and surrounding the corpus spongiosum. In select cases, a contrast US urethrogram confirmed the presence of urethral disruption with extravasation of microbubbles into the perispongiosal tissues (Figure 2).

Suspensory ligament or bulbocavernosal rupture were solely diagnosed by MRI. The diagnosis was made by the presence of dorsal penile angle haematoma or oedema with disruption of the T2 bands of the suspensory ligament or focal oedema in the bulbospongiosal muscles.

Dorsal vein rupture was diagnosed by oedema/haematoma surrounding the dorsal vein or its main tributaries and presence of a thrombosed or abnormal signal dorsal vein in the absence of peritunical haematoma or tunical disruption (Figure 3).

Statistical analysis

Descriptive statistics were used to define the study groups and outcomes.

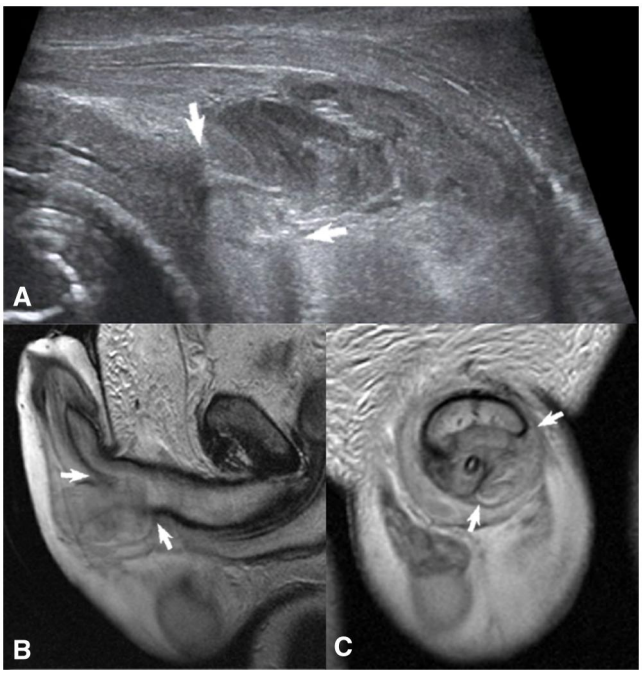

Figure 1. (A) Longitudinal ultrasound image of the penis scanned ventrally at midshaft level. Large defect in the tunica is indicated by the white arrows—a large haematoma is seen bulging out of the defect. (B) Sagittal T2W MRI section of the same patient demonstrating the defect in the continuous black line of the tunica (white arrows). (C) Axial T2W MRI section demonstrating the defect is localized to the ventral left corpus cavernosum, where the haematoma (white arrows) can be seen pushing the corpus spongiosum (catheter seen in the urethra) to the right.

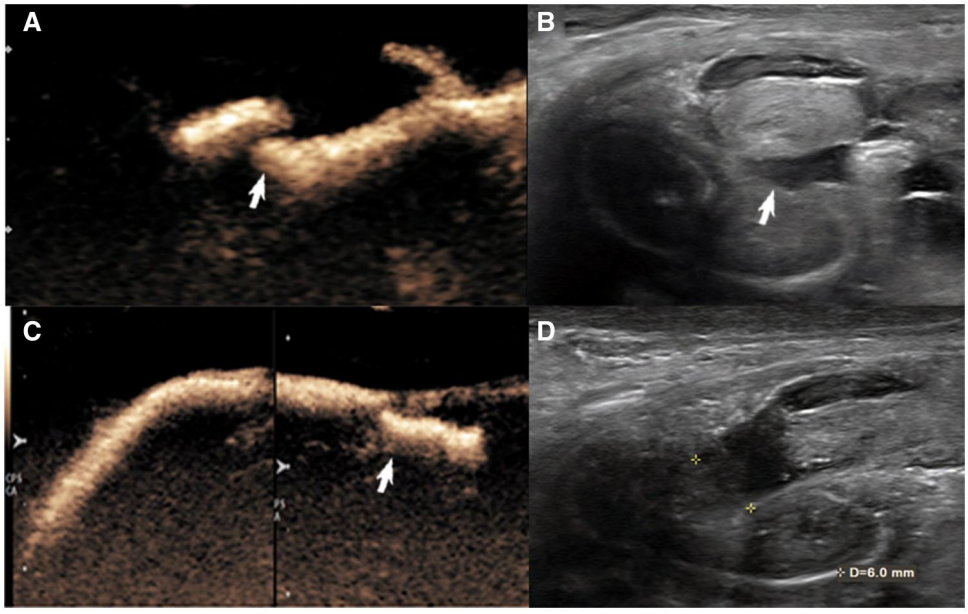

Figure 2. (A and C) Axial and longitudinal contrast enhanced ultrasound of the corpus spongiosum demonstrating extravasation of the microbubbles into the perispongiosal tissues under Buck's fascia (white arrow) at the site of urethral injury. (B and D) Axial sections of the penis at adjacent levels at the penoscrotal junction, showing the urine collection under Buck's fascia (B: white arrow) and the 6-mm defect in the ventral tunica albuginea of the right corpus cavernosum (D: yellow callipers).

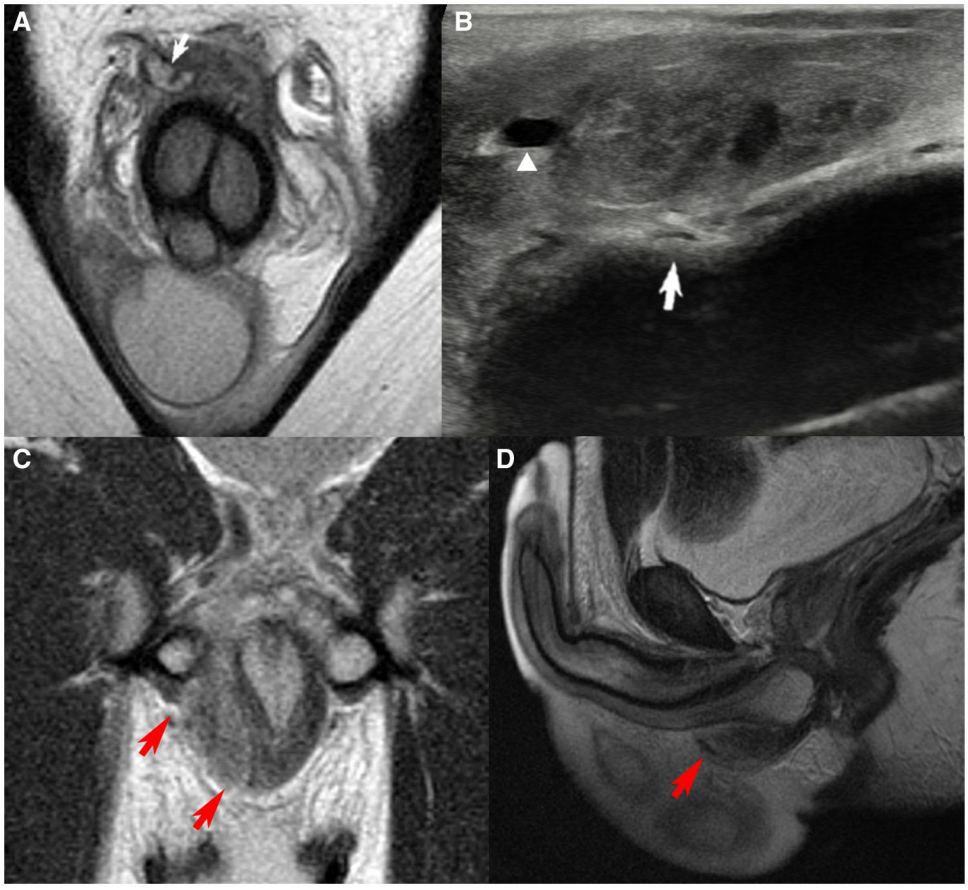

Figure 3. (A) Axial MRI T2W image showing a high signal collection with surrounding low T2w signal at the dorsum of the penis, the normal continuous low T2W band of the tunica is seen intact. This is in keeping with a haematoma related to dorsal vein rupture. (B) Longitudinal ultrasound image centred on the dorsum of the penis showing a large haematoma superficial to the tunica (white arrow) and related to a vascular structure (white arrow head) which represents the ruptured dorsal vein. (C and D) Axial and sagittal T2W MRI images showing an intermediate low T2W collection centred between the crus of the right corpus cavernosum and indenting the right side of the corpus spongiosum. This is in keeping with a haematoma related to rupture of the bulbospongiosus muscle.

Surgical exploration (where performed) was used as the gold standard test. Comparison of continuous variables between imaging and surgical findings were made using non-parametric test (Mann-Whitney *U* test). Continuous variables were presented as median, IQR unless otherwise specified. *P* values <.05 were considered significant. Analysis was performed with SPSS® statistical package version 22 (IBM Corp, Armonk, NY, United States).

Ethical consideration

This study was not subject to formal ethics committee and is considered an audit of practice as per the NHS health research authority.

Results

One hundred and ninety-three emergency referrals were made with suspected PF (by clinical diagnosis) between 2010 and 2021 and underwent dedicated penile imaging before consideration of surgery; 99/193 proceeded to surgical exploration; 94/193 did not have surgical exploration.

Median age was 37 (IQR 32-48) years. Injury was during sexual intercourse in 186 cases (96%) and masturbation or Taghaandan practice in 7 (4%).

Median time from presentation to surgery was 47 h (IQR 24-72 h). All patients were admitted to an inpatient bed and imaging was performed the same day as surgery in 61 cases (68%) and within 24 h prior to surgery in a further 29 cases (29%), all imaging was performed within 48 hours of referral.

Surgical cases

Ninety-nine patients underwent surgical exploration: 89 (46%) had confirmed PF and 10 patients had no PF on surgical exploration (finding was of peritunical haematoma) see Table 1.

US findings

US was carried out in 97/99 (98%) cases before surgical exploration. The positive predictive value of US for diagnosis of PF was 92%.

In 12 cases, the US over or under called a fracture: there were 7 false positives with only contusion with an absence of tunical breach found on surgical exploration; and 5 false negatives on US however due to diagnostic uncertainty a subsequent MRI, upgraded the diagnosis to fracture in all cases and confirmed presence of a tunical rupture on surgical exploration, see Table 2.

In 42 cases, a skin pen mark was placed on the skin at the time of US; this was reported to be correctly placed at the site of fracture and guided a focal surgical incision in all cases.

Table 1. Surgical findings of 99 patients proceeding to surgical exploration.

Unilateral injury	74
Bilateral injury	15
Urethral injury	23
Corpus spongiosal injury (without urethral injury)	4
No fracture present	10
Size of defect (cm)[a]	2.0 (IQR 10-30)

[a]Where documented in operation note (median, IQR).

In 5 cases, agitated saline contrast enhanced US urethrography confirmed a urethral rupture.

MRI findings

MRI was performed in 15 cases that underwent surgical exploration. In 13 cases, MRI was preceded by US and in 2 cases MRI was the primary imaging modality. The decision to perform MRI was made when US was technically challenging due to a crural position of the injury, gross swelling of the penis inhibiting adequate views of the tunica and in 2 cases when the patient was unable to tolerate US transducer pressure. In 12 cases, PF was present on exploration; in 1 case, there was a false positive on both US and MRI with no fracture seen on exploration but a focal peritunical haematoma at the marked site.

MRI correctly diagnosed a fracture in 5 cases in which US had not previously identified a tunical defect.

In 7 cases, MRI was performed as a problem-solving tool to better define the extent of injury identified on US. In all 7 cases, MRI suggested a more extensive injury than that seen on US including contralateral and corpus spongiosal injury. In 5 cases, subsequent surgical exploration agreed with the MRI; however, in 2 of these cases, only a single corpus was involved, that is, MRI overcalled a contralateral injury.

Two cases had only MRI before surgery. In both cases, MRI correctly diagnosed and staged the PF.

Levels of agreement

Expert imaging review did not reveal any discrepancy with the original reports; however, in 12 studies, retrospective measurement of the tunical defect was performed from representative B-mode images when not specifically documented in the initial US report.

Size and position of defect

The median size of the tunical defect measured on US was 7 mm (IQR 5-10 mm) and on MRI 4 mm (IQR 35-10 mm) the difference was not statistically significant (*P*-value 0.1096). The median tunical defect on all imaging modalities was 7 mm (IQR 4-10 mm). The median size of defect measured on surgical exploration was 20 mm (IQR 10-30 mm), significantly larger than the imaging predicted measurement ($P < .0001$). The most common site for tunical injury were the ventral aspect of the penoscrotal junction (66%) followed by the midshaft level (15%). Crural/perineal and distal injuries were uncommon but seen in 5%, respectively.

Alternative diagnoses

One hundred and four (54%) patients in total had an alternative diagnosis to PF including dorsal vein rupture and haematoma. Prior imaging suggested an alternative diagnosis to PF in 94 cases (48%) and this group were not surgically explored after careful clinical assessment; 10 cases were found to have an alternative diagnosis to PF on surgical exploration, see Table 3.

Clinical follow-up in andrology outpatients' clinic occurred in 39 (40%) of this group of patients at a 3-month interval. Patients reported normal sexual function with normal spontaneous erections in 32 (82%), 5 (13%) had Peyronie's disease and 3 (7%) had de novo erectile dysfunction requiring oral PDE5 inhibitors. No routine imaging was performed in this cohort.

Table 2. Comparison of ultrasound and intraoperative surgical findings in 97 cases with US prior to surgical exploration.

	Overall detection of PF, *n* (%)	Bilateral tunical defect, *n* (%)	Urethral rupture, *n* (%)	Corpus spongiosal rupture, *n* (%)
TP: Finding on surgical exploration	87 (90)	15 (15)	23 (24)	20 (21)
FP	7 (7)	9 (9)	2 (2)	8 (8)
FN	5 (5)[a]	8 (8)	13 (13)	4 (4)
PPV	92	64	92	71

[a]In all cases a subsequent MRI confirmed PF confirmed on surgical exploration.
Abbreviations: FN = false negative; FP = false positive; PPV = positive predictive value; TP = true positive.

Table 3. Alternative diagnoses to penile fracture.

	US	MRI	US + MRI	Total
DVR	19	0	6	25 (29%)
Haematoma	23	6	5	34 (37%)
Muscle/SL rupture	2	1	1	4 (3%)
Soft tissue oedema	14	9	6	29 (31%)

Abbreviations: DVR = dorsal vein rupture; SL = suspensory ligament; US = ultrasound.

Discussion

Patients presenting with penile trauma can be a diagnostic dilemma. Most centres depend on clinical examination to diagnose PF followed by surgical exploration. The present study confirms, in the largest cohort of patients to date, that the rate of negative exploration for PF on dedicated penile imaging could be as high as 54%. Imaging with US and in selected cases, additional MRI correlated closely to findings on surgical exploration with a high positive predictive value should be offered routinely prior to surgical exploration.

Over an 11-year period in a large specialist Andrology centre in the United Kingdom, 193 patients (approximately 20 patients per year) were seen with a history of blunt trauma to the erect penis. These data found 46% of patients who presented with a history of trauma to the erect penis had a PF identified on imaging and confirmed by surgical exploration. Most commonly the injury was in a ventral position at the penoscrotal junction level (69%). Surgical exploration remains the gold standard investigation for suspected PF. Therefore, patients should be explored where the clinical suspicion remains high despite negative findings on imaging.

In published series of suspected PF proceeding directly to surgical exploration, between 16% and 52% were reported to have dorsal vein rupture on surgical exploration despite a clinical history and examination consistent with PF.[2,9] In other series that included imaging in the assessment of suspected PF, 25 out of 37 (67%) cases who underwent US had an alternative diagnosis other than tunical rupture[10] including soft tissue oedema, haematoma and dorsal vein rupture.

The published literature on the diagnostic accuracy of imaging for PF reports a sensitivity between 55% and 100% (see **Appendix**).[11-16]

In the present cohort, US was the most frequent initial imaging investigation and had a positive predictive value of 92%. Subsequent MRI was used as a problem-solving tool to better delineate the extent of injury or where there was suspicion on US but in an atypical location for fracture. MRI has been previously reported to have greater sensitivity than US,[12] and in this cohort, MRI confirmed a suspected crural tunical fracture in 3 cases, which is both an unusual location and technically difficult area to identify PF on US.[17] US had a reduced detection rate for bilateral injury (50% sensitivity, 62% positive predictive value); however, this had limited clinical consequence as the identification of a unilateral injury would necessitate surgical exploration irrespectively (see Appendix Table 5). Adjunctive techniques such as urethrography with urethral instillation of US contrast/agitated saline may improve the detection of concurrent urethral injuries[18] and used successfully in 5 cases in this series.

These data highlight the important role of acute imaging in suspected PF to confirm or refute the diagnosis and identify the extent and location of structures involved.[6,8,19] Skin marking at the time of US guides surgical planning of the location and extent of incision. A ventral midline (penoscrotal) incision rather than circumcising-degloving (subcoronal) incision can therefore be used. This will minimise the risk of skin necrosis or sensation loss from injury to the neurovascular bundle.[3] Circumcision is also mandatory when degloving but may be avoided using the penoscrotal approach.

Imaging may underestimate the size of the tunical defect by nearly two thirds, which has been reported before.[11] This underestimation is likely due to the buckling of the ruptured tunica and haematoma compressing the edges of the defect together and therefore surgical teams should be cognizant that the extent of injury on exploration may be more significant than suggested by imaging.

Guidelines recommend prompt surgical repair of PF, often within 24 h of diagnosis but ideally within a week.[8] The need for imaging should not delay surgical decision-making because clinical assessment can be sufficient for diagnosis.[20] The vast majority of imaging in this study (90%) was performed within 24 h of presentation to hospital because of the comprehensive service offered by 8 consultant genitourinary radiologists. Similar access to imaging may not be possible in many centres. A low threshold for imaging in suspected PF is proposed to confirm the diagnosis of tunical rupture and to aid skin marking of the fracture site to guide surgical approach. A high rate of alternative diagnoses to PF was seen in this retrospective study (54%); therefore, penile imaging in suspected PF could help clinical decision-making and avoid unnecessary surgery; however, more detailed and comprehensive prospective data are required to support the routine use of imaging.

Limitations of this study include a non-standardized imaging protocol with various combinations of US and MRI. Of those patients without an imaging diagnosis of PF only 3 underwent surgical exploration therefore sensitivity, specificity and negative predictive values of imaging cannot be determined. Furthermore, this study excluded patients without prior penile imaging who proceeded to surgery. This potentially biases the study cohort to those with potentially more equivocal clinical presentation prompting imaging, which limits the reproducibility of the findings.

Conclusion

US is a highly predictive tool in the diagnosis of PF and can identify alternative diagnoses in acute trauma to the erect penis and mark the skin to aid surgical approach decisions. The addition of MRI improves the detection of PF and is a useful problem-solving tool in cases of equivocal US findings and unusual locations of injury. History and clinical diagnosis may remain the mainstay of diagnosis at many centres but the clinician should have a low threshold to consider imaging given the high prevalence of alternative imaging diagnoses to PF, seen in 54% of men in this study.

Supplementary material

Supplementary material is available at *BJR* online.

Funding

None declared.

Conflicts of interest

None declared.

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British Journal of Radiology, 2024, 00, 1–6
https://doi.org/10.1093/bjr/tqae167
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