



A pilot study on surgical reduction of the levator hiatus—the puborectalis sling

Vivien Wong^{1,2} · Ka Lai Shek³ · Andrew Korda⁴ · Chris Benness⁴ · John Pardey⁵ · Hans Peter Dietz¹

Received: 8 April 2019 / Accepted: 16 July 2019 / Published online: 6 August 2019
© The International Urogynecological Association 2019

Abstract

Introduction and hypothesis Female pelvic organ prolapse recurrence has been shown to be associated with levator hiatal distensibility. Reducing hiatal size surgically may reduce recurrence risk. This study aims to demonstrate a novel surgical procedure, the puborectalis sling (PR sling), designed to reduce the levator hiatal area, and to assess the medium-term safety and efficacy of this procedure.

Methods One hundred fifteen women undergoing prolapse repair with a pre-operative hiatal area on Valsalva of ≥ 35 cm² were recruited into this phase 1 prospective multicentre pilot study. All underwent a PR sling procedure after completion of standard repairs. Primary outcome was levator hiatal area measured on ultrasound.

Results One hundred ten patients were evaluated at least 3 months post-operatively. At 2.5 years average follow-up, there was an average of 12 cm² (range 6–16 cm²) reduction in hiatal area from a mean pre-operative hiatal area of 43.9 (35–63) cm². Thirty per cent (28/93) were symptomatic of prolapse, 66% (61/93) had clinical prolapse recurrence whilst 49% (46/93) had sonographic recurrence. Three patients required a return to theatre; one case of infection resulted in mesh removal, one had severe obstructed defecation requiring sling loosening and another had buttock pain with faecal impaction that resolved after manual disimpaction. There were no long-term sequelae.

Conclusions The levator hiatal area can be reduced surgically, with almost 30% reduction in area seen in this pilot study. The reduction was significant and sustained up to 2 years with no major long-term complications.

Keywords Pelvic organ prolapse · Levator hiatal area · 3D pelvic floor ultrasound · Prolapse recurrence · Mesh

Abbreviations

Gh	Genital hiatus
Pb	Perineal body
POP	Pelvic organ prolapse
POPQ	Pelvic organ prolapse quantification

PR	Puborectalis
TOPAS	Transobturator Post-anal sling
US	United States of America

This was presented as an e-poster at IUGA 42nd ASM, Vancouver, June 2017.

✉ Vivien Wong
vivwlp@yahoo.co.nz

- ¹ Nepean Clinical School, University of Sydney, Penrith, Australia
- ² Nepean Hospital, University of Sydney, Penrith, New South Wales, Australia
- ³ Liverpool Clinical School, Western Sydney University, Sydney, Australia
- ⁴ Royal Prince Alfred Hospital, Camperdown, NSW, Australia
- ⁵ Nepean Private Hospital, Penrith, Australia

Introduction

Pelvic organ prolapse (POP) is a common condition with reported prevalence rates ranging from 2 to 48% [1]. The condition accounts for a 10–20% lifetime risk of requiring surgery [2, 3]. There is a high recurrence rate following repair, with almost one in three women needing further prolapse surgery [4]. The high rates of failure have led to the development of vaginal mesh kits. Whilst mesh reinforcements have been shown to reduce recurrence [5], their use is not innocuous. Mesh complications such as chronic pelvic pain, dyspareunia, mesh infection and erosion have brought vaginal prolapse mesh into disrepute [6].

To address the issue of prolapse recurrence, it is important to understand and modify risk factors. There is a growing body of evidence identifying excessive distensibility of the levator ani muscle and levator avulsion as important risk factors for prolapse recurrence [7–11]. The latter is a form of birth trauma sustained by 10–30% of women following their first vaginal delivery [12, 13]. These injuries most likely occur at the time of fetal head crowning [14, 15] and markedly increase the risk of POP, especially anterior and apical prolapse [14, 15]. Apart from macroscopic muscle tears, the degree of muscle stretching/lengthening during vaginal delivery may also cause permanent over-distension of the levator hiatus. In an observational study, up to 28% of primiparous women had sustained enlargement of the hiatal area by > 20% by the time of their postpartum assessment [16]. A follow-up study suggested that childbirth-related changes to levator distensibility may not regress with time [17]. An enlarged levator hiatus implies greater loading of any structure supporting the pelvic organs, whether the supportive structure is native tissue, suture or mesh. This may explain the association between an enlarged hiatal area and increased incidence of prolapse recurrence.

In the US, a surgical procedure involving the placement of a mesh sling in the ischio-rectal fossa, from one obturator foramen to the anococcygeal raphe and back to the contralateral side, has been trialled in patients with faecal incontinence [18]. In this study by Rosenblatt, there were no significant procedure-related adverse events in a series of 29 women. Our PR sling procedure differs in that the mesh sling is secured onto the pubic rami and that the aim is to reduce the hiatal area, which may result in reduction of prolapse recurrence.

In this study, we intended to demonstrate proof of concept by using a mesh as a brace around the levator hiatus to permanently reduce the distensibility of the levator ani as well as to assess the medium-term safety and efficacy of this novel surgical procedure. The study served as preparation for an ongoing randomized controlled trial designed to ascertain the effect of this procedure on prolapse recurrence.

Materials and methods

One hundred fifteen patients were enrolled in this surgical pilot study conducted at two tertiary centres in 2010–2012. The primary inclusion criteria were (1) patient requiring surgery for symptomatic pelvic organ prolapse and (2) an enlarged hiatal area on Valsalva of ≥ 35 cm². The latter criterion was selected to limit this phase I clinical trial to patients at high risk of prolapse recurrence. Patients with overt neuromuscular abnormalities, who had not completed their family and who were unable to provide informed consent were excluded. Primary outcome was hiatal area measurement on Valsalva obtained by transperineal ultrasound; secondary

outcomes were subjective and objective findings of pelvic organ prolapse recurrence.

Written consent was obtained from all patients. The operation was performed under general anaesthesia with full muscle relaxation. The PR sling was inserted after completion of the prolapse repair. For PR sling placement, a groin incision was made at the level of the clitoris on both sides as for placement of a transobturator sling. Vertical perianal incisions of 2 cm length, 3 cm lateral and 3 cm inferior to the anus were made bilaterally. A tunnel was created digitally just below the anococcygeal raphe, connecting the two perianal incisions. A 3 cm \times 25cm strip of type 1 polypropylene mesh (Johnson & Johnson/Ethicon, Somerville, NJ) was passed through this tunnel with the help of an angled clamp. A curved Stamey needle (90° curvature) was inserted through the obturator foramen via the groin incision, traversing the ischio-rectal fossa to exit in the ipsilateral perianal incision to retrieve one end of the mesh sling. Needle insertion was performed under digital guidance (vaginal and rectal) to ensure that the mesh sling was placed as medially as possible, along the course of the puborectalis muscle, without perforating or tethering the vagina or rectum; see Fig. 1.

The sling was tightened to obtain a genital hiatus and perineal body (Gh + Pb) measurement of approximately 7 cm, which is regarded as the limit of normal [19]; see Fig. 2. The mesh sling was then secured to the periosteum of the inferior pubic rami on both sides, using delayed absorbable sutures. All patients were given intra-operative antibiotics (cefotaxime and metronidazole). After the first few cases we used pre-operative bowel preparation to facilitate post-operative defecation.

As part of the research protocol, post-operative follow-up visits were scheduled at 3, 6, 12 and 24 months with a standardized interview, POPQ clinical assessment and 4D transperineal ultrasound. The latter was performed in the supine position after bladder emptying using either GE Voluson 730 Expert or E8 systems (GE Medical Kretz Ultrasound, Zipf, Austria) with an 8–4-MHz curved array volume transducer. The acquisition angle was set at 85° as previously described [20]. Pelvic organ descent and hiatal area were measured using volumes acquired at maximum Valsalva, according to published methodology [21]. Hiatal area on Valsalva was measured using the rendered volume technique, with the region of interest set at 1–2 cm thickness at the plane of minimal hiatal dimension [22]. All ultrasound images were analysed using proprietary software (4D View v 10) at a later date, with the assessor blinded to all clinical data.

Subjective prolapse recurrence was defined as feeling or seeing a vaginal lump/bulge and/or a dragging sensation. Clinical prolapse recurrence was defined as POPQ stage 2 or higher in the anterior/posterior and \geq stage 1 in the central compartment. Sonographic recurrence was defined as (1) a maximum bladder descent of ≥ 10 mm below the symphysis

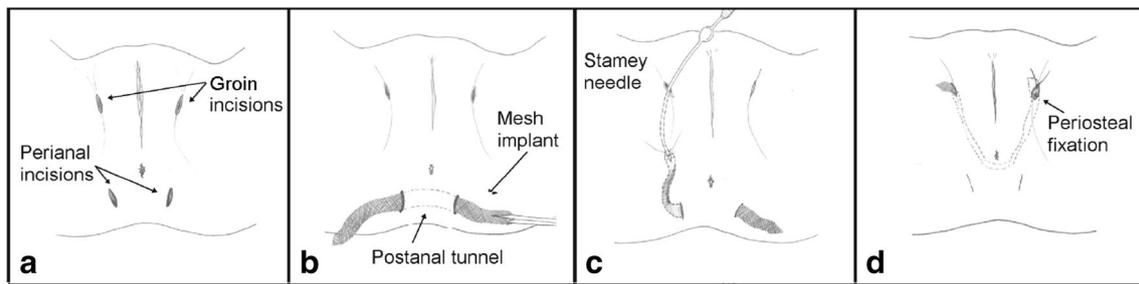


Fig. 1 Puborectalis sling procedure. A shows the incisions, B insertion of the implant, C its retrieval by curved needle and D anchoring of the implant to the inferior pubic ramus

pubis, (2) the uterus at the level of the symphysis pubis or (3) the descent of the rectal ampulla to ≥ 15 mm below the symphysis pubis.

Levator integrity was assessed using tomographic ultrasound imaging, employing a previously described methodology [23]. Levator avulsion was diagnosed if the muscle was disconnected from the sidewall at the plane of minimal hiatal dimension and two other slices at a 2.5-mm interslice interval cranial to this plane. In doubtful cases, the levator-urethra gap measurement was used [24].

This study was approved by the local Human Research Ethics Committee (NBMLHD HREC 10-03). Power calculations were not performed because of the pilot nature of this study, with no input data available in the literature. Statistical analysis was performed using Minitab version 13 (Minitab Inc., State College, PA, USA). Student's *t*-test was performed for continuous variables and *chi*² analysis for categorical variables. A *p* value of < 0.05 was considered to be statistically significant.

Results

Among the 115 patients recruited and operated on, 113 (98%) returned for at least one post-operative assessment with a mean follow-up interval of 2.53 (1.72–5.98) years. Demographic and pre-operative clinical and sonographic findings are presented in Table 1.

All patients were symptomatic of prolapse and all had prolapse of \geq stage 2 in at least one compartment. There were 69 patients with \geq stage 3 anterior compartment descent, 83 \geq stage 3 apical compartment descent and 67 \geq stage 3 posterior compartment prolapse. Stress urinary incontinence was reported in 68 (59%), urge incontinence in 82 (71%), voiding difficulties in 52 (45%), obstructed defecation in 40 (35%) and anal incontinence in 19 (17%). Pre-operatively, mean bladder descent was 25 mm (range – 65 to 66) below the symphysis pubis, mean uterine/vault descent was 24 mm (range – 60 to 30) below the symphysis pubis, mean enterocele position was 28 mm (range – 54 to 40) below the symphysis pubis and the rectal ampulla was 21 mm (range – 45 to 18) below the symphysis pubis. Mean hiatal area on Valsalva was 43.5 (range 35–63) cm² and 75/115 (65%) had severe hiatal ballooning (≥ 40 cm²). Levator avulsion was diagnosed in 73 (63%).

A vaginal hysterectomy was performed in 47 women, a vault suspension in 66, an anterior repair in 95 and a posterior repair in 80. A transobturator anterior anchored mesh was inserted in 37 (28 anterior Perigee™, 6 anterior Elevate™ and 3 Uphold) and a mid-urethral sling in 38. There were no cases of vaginal or rectal/anal perforations or major intra-operative complications with the puborectalis sling insertions. There was one case of rectal perforation during a concomitant Miya hook sacrospinous colpopexy. The suture was removed immediately with no adverse sequelae. There was one case of inadvertent cystotomy during vault dissection for sacrospinous fixation, which was recognized in theatre and



Fig. 2 Puborectalis sling procedure. Image from left to right depicts measurement of Gh & Pb, insertion of the sling through the post-anal tunnel, retrieval of the mesh with the Stamey needle, securing the mesh

onto the periosteum of the pubic rami and the final measurement of Gh & Pb reduction at the conclusion of the surgery

Table 1 Demographic and clinical characteristics of the patient population

Patient characteristics	Values
Age (years), mean (range)	60 (29–88) years
BMI, mean (range)	29 (17–44) kg/m ²
Vaginal parity, mean (range)	3 (0–10)
Previous operative delivery	27/115 (23%)
Previous surgery	
Hysterectomy (%)	52/115 (45%)
Incontinence/prolapse surgery (%)	38/115 (33%)
Pre-operative diagnosis of significant POP:	
Anterior compartment (%)	101/115 (88%)
Apical compartment (%)	95/115 (83%)
Posterior compartment (%)	78/115 (68%)
Pre-operative imaging	
Hiatal area on Valsalva (mean, range)	43.5 (35–63) cm ²
Levator avulsion (%)	73/115 (63%)
Unilateral, <i>n</i>	44
Bilateral, <i>n</i>	29

repaired without any long-term consequences. There were two cases of infra-pubic needle passage during PR sling placement and several cases of mesh dislodgements from the needle on mesh retrieval, necessitating repeated Stamey/Pereyra needle passes. The maximum number of needle passes on one side was three. No procedure had to be abandoned for any reason.

In the post-operative period, one patient required removal of the PR sling on day 10 because of infection. Another woman had periosteal sutures cut bilaterally on day 9 because of worsened obstructive defecation. One additional woman had an examination under anaesthesia for severe buttock pain on day 10. She was found to have significant faecal impaction that was addressed in theatre without requiring sling adjustment. She had a fleet enema as well with good effect and resolution of pain.

There were no cases of puborectalis sling erosion observed during the 24-month follow-up period. There were several cases of mesh erosions into the vagina during the follow-up period, all related to Perigee™ mesh (see Table 4). All resolved with conservative care except two with an erosion of ≥ 5 mm, who underwent mesh trimming in clinic at approximately 12-month post-operative follow-up.

Five patients required further procedures for symptomatic prolapse during the follow-up period: one had a Perigee™ insertion with bilateral sacrospinous fixation, two had revision of Perigee™ and posterior repair with bilateral sacrospinous fixation, one had a posterior repair with bilateral sacrospinous fixation and the fifth patient had a Perigee™ with posterior repair and a repeat puborectalis sling insertion 18 months following her initial surgery. One patient required a transobturator sling for USI at 12 months following surgery and another patient underwent a Delorme's procedure for rectal prolapse 6 months after the index surgery.

There were 18/110 (16%) patients who reported de novo dyspareunia at the 3-month post-operative mark and 23/93 (25%) total number of patients reporting dyspareunia at 24 months post-operation. Of those, 10/93 (11%) were persistent from the 3-month post-operative mark. At 24 months post-operation, in most cases of dyspareunia, this was superficial or introital, the majority had mild superficial dyspareunia. Seven of 23 (30%) patients reported deep dyspareunia. In one case, the pain was located at the left anterior arm of a Perigee mesh. We documented no case with pain on palpation of the puborectalis sling. One patient reported anal/gluteal pain at the 3-month post-operative mark but this had resolved spontaneously by the time of her 6-month post-operative visit.

Subjective and objective outcomes at each follow-up time point are shown in Table 2. Table 3 shows a breakdown of significant clinical prolapse recurrence in individual compartments at follow-up. Urinary and bowel function outcomes over each follow-up time point are shown in Table 4. The reduction in hiatal area, compared with pre-operative

Table 2 Subjective and objective outcomes after prolapse repair with puborectalis sling at 3, 6, 12 and 24 months

Parameter	Pre- op status (<i>n</i> = 115)	3 m postop <i>n</i> = 110	6 m postop <i>n</i> = 106	12 m postop <i>n</i> = 92	24 m postop <i>n</i> = 93
Subjective satisfaction	–	95/110 (86%)	88/106 (83%)	77/92 (84%)	73/93 (78%)
Subj. improved/ cured	–	99/110 (90%)	98/106 (92%)	82/92 (89%)	81/93 (87%)
Prolapse symptoms	115	18/110 (16%)	24/106 (23%)	22/92 (24%)	28/93 (30%)
Clinical recurrence in any compartment	–	80/110 (73%)	77/106 (73%)	71/92 (77%)	61/93 (66%)
Significant prolapse on ultrasound ^a	113	50/110 (45%)	54/106 (51%)	52/92 (57%)	46/93 (49%)
Hiatal area on Valsalva, mean (cm ² , SD)	43.5 (6.5)	30.5 (6.2) ^b	31.0 (6.9) ^b	32.1 (7.6) ^b	31.8 (7.5) ^b

^a Cystocele ≥ 10 mm below symphysis pubis (SP), uterus ≤ 15 mm above SP, rectal ampulla ≥ 15 mm below SP

^b Reductions in hiatal area all $p < 0.001$ at 3, 6, 12 and 24 months

Table 3 POPQ assessment pre-operation and at 3, 6, 12 and 24 months post-operation

Follow-up time points	≥ ICS POPQ stage 2 anterior	≥ ICS POPQ stage 2 posterior	≥ ICS POPQ stage 1 apical
Pre-operatively	101/115 (88%)	78/115 (68%)	95/115 (83%)
3 months post-operation	60/110 (55%)	32/110 (29%)	20/110 (18%)
Mean POPQ (range)	Ba -1 (-3 to 5)	Bp -2 (-3 to 2)	C -6 (-10 to 6)
6 months post-operation	57/106 (54%)	29/106 (27%)	22/106 (21%)
Mean POPQ (range)	Ba -1 (-3 to 5)	Bp -2 (-3 to 2)	C -5 (-9 to 6)
12 months post-operation	58/92 (63%)	37/92 (40%)	25/92 (27%)
Mean POPQ (range)	Ba -1 (-3 to 5)	Bp -2 (-3 to 3)	C -5 (-9 to 7)
24 months post-operation	45/93 (48%)	33/93 (35%)	22/93 (24%)
Mean POPQ (range)	Ba -1 (-3 to 5)	Bp -2 (-3 to 5)	C -5 (-8 to 5)

measurements, was highly significant at all follow-up time points and was maintained throughout the 2-year follow-up period (Table 2).

Discussion

In this pilot study investigating a novel surgical procedure, we have shown that the levator hiatal area can be successfully reduced with a mesh sling, the puborectalis sling, providing proof of concept. A significant reduction in levator hiatal area was seen in 110 patients with an 81% follow-up rate at the 2-year mark. On average, the levator hiatal area was reduced by 12 cm², which equates to a reduction of almost 30%. The effect was sustained up to 2 years post-operatively with no major long-term complications related to the puborectalis sling.

Despite an anatomical recurrence of 66% at 24 months post-operation, only 30% were symptomatic of prolapse and < 10% required re-operation for their prolapse. The

high rate of objective prolapse recurrence is likely due to strict definitions (POPQ stage 2 anterior and posterior compartment, stage 1 central compartment) and the fact that we performed this study exclusively in patients at high risk of recurrence, resulting in an average pre-operative hiatal area > 43 cm² and a very high avulsion rate of 63% in this cohort.

The insertion of the puborectalis sling at the completion of prolapse surgery is a novel surgical approach based on a perception of pelvic organ prolapse as a hernia through the levator hiatus. Since this hernia portal cannot be obliterated (like in the case of umbilical hernia), or nearly obliterated (as in the case of femoral or inguinal hernia), the only option is to reduce its size permanently. While this has been attempted by the abdominal route, this approach is highly morbid and was abandoned decades ago [25].

The puborectalis sling is based on the TOPAS posterior anal sling [26], but it uses a wider mesh and requires anchoring to the periosteum of the inferior pubic rami. Although tunnelling post-anally towards the anococcygeal

Table 4 Symptomatic outcome of urinary and bowel function at each follow-up time point

Parameters	Pre-operation (n = 115)	3 months post-operation (n = 110)	6 months post-operation (n = 106)	12 months post-operation (n = 92)	24 months post-operation (n = 93)
Urinary incontinence					
Stress	68 (59%)	21 (19%)	19 (18%)	16 (17%)	30 (32%)
Urge	82 (71%)	41 (37%)	31 (29%)	31 (34%)	49 (53%)
Voiding difficulty	52 (45%)	19 (17%)	27 (25%)	35 (38%)	29 (31%)
Mesh erosion	–	4 (4%)	3 (3%)	3 (3%)	2 (2%)
Obstructed defecation	40 (35%)	23 (21%)	18 (17%)	21 (23%)	28 (30%)
Faecal incontinence (FI)	19 (17%)	12 (11%)	10 (9%)	10 (11%)	11 (12%)

All mesh erosions were secondary to Perigee™ mesh

raphe may prove to be unfamiliar to gynaecologists/urogynaecologists, there were no reported intra-operative complications directly related to the anchoring and placement of the puborectalis sling. Hence, the method seems to be technically feasible and accessible to most female pelvic floor reconstructive surgeons.

Three cases required return to the operating theatre during the study period. One was in a patient with type 2 diabetes and chronic pelvic pain. She developed persistent pain and progressive erythema at the peri-anal incision sites, unresponsive to antibiotics. Removal of her puborectalis sling on day 10 involved re-opening of the transobturator incision sites bilaterally, dividing of the anchoring sutures and removal of the sling in toto via one of the peri-anal incisions.

The second patient required a return to the operating theatre because of faecal impaction on day 9. Her puborectalis sling was released by re-opening the groin incisions, cutting the anchoring sutures bilaterally and applying downward vaginal/anal traction to loosen the sling. Her symptoms resolved immediately after sling release. The third patient who also suffered from faecal impaction had an examination under anaesthesia only with conservative treatment. All patients recovered well with no long-term sequelae.

There are several limitations of this study that need to be addressed. First, we did not acquire validated questionnaires pre-operatively; therefore, evaluation of subjective outcomes was dependent on the physician-directed interview. Although this may not evaluate subjective outcome comprehensively, this question was asked in an identical fashion before and after the procedure and has been found sensitive to prolapse recurrence [27]. At any rate, our primary aim was to evaluate anatomical changes following insertion of the PR sling and not subjective outcomes.

Second, this study was performed at two tertiary centres involving two urogynaecology subspecialist surgeons, subspecialty fellows and specialist trainees. It is possible that heterogeneity of surgical practice may have affected outcomes. However, we believe that our results are reflective of standard subspecialty practice at a public hospital, where different surgeons of varied skills are involved in patients' care and surgery. As a result, we feel that our results may be widely generalizable.

The association between levator hiatal area enlargement, pelvic organ prolapse and recurrence has been comprehensively demonstrated [10, 11]. Thus, the ability to reduce the levator hiatal area as shown in this pilot study is potentially an important step forward in optimizing prolapse surgery outcomes. In this study, the majority of our patients had severely compromised pelvic floor muscle support. Therefore, any surgical attempt to treat prolapse in this cohort would be challenging. After proving the feasibility of hiatal reduction with an acceptable short- and medium-term safety profile, we are

now performing a randomized controlled trial evaluating the puborectalis sling as an adjunct to conventional prolapse surgery. Recruitment is nearly complete at the time of writing. However, it is already evident that biomechanical properties of implants play a larger role than expected, and we are continuing the search for optimal materials to be used in hiatal reduction surgery.

In conclusion, this observational trial of a novel surgical procedure has shown that the levator hiatus can be reduced safely and efficiently with a 'puborectalis sling'. The resulting reduction in hiatal area on Valsalva is sustained to at least 2.5 years after the procedure.

Compliance with ethical standards

Conflicts of interest HP Dietz and KL Shek have received unrestricted educational grants from GE. No other conflicts of interest to declare by other authors.

References

1. Brubaker L, Maher C, Jacquelin B, Rajamaheswari N, von Theobald P, Norton P. Surgery for pelvic organ prolapse. *Female Pelvic Medicine & Reconstructive Surgery*. 2010;16(1):9–19.
2. Olsen AL, Smith VJ, Bergstrom JO, Colling JC, Clark AL. Epidemiology of surgically managed pelvic organ prolapse and urinary incontinence. *Obstet Gynecol*. 1997;89:501–6.
3. Smith F, Holman D, Moorin R, Tsokos N. Lifetime risk of undergoing surgery for pelvic organ prolapse. *Obstet Gynecol*. 2010;116:1096–100.
4. Hagen S, Stark D. Conservative prevention and management of pelvic organ prolapse in women. *Cochrane Database Syst Rev*. 2011;12:CD003882.
5. Altman D, Väyrynen T, Ellström Engh M, Axelsen S, Falconer C. Anterior colporrhaphy versus transvaginal mesh for pelvic-organ prolapse. *New Engl J Med*. 2011;364:1826–36.
6. Feiner B, Jelovsek J, Maher C. Efficacy and safety of transvaginal mesh kits in the treatment of prolapse of the vaginal apex: a systematic review. *Br J Obstet Gynaecol*. 2009;116:15–24.
7. Model A, Shek KL, Dietz HP. Levator defects are associated with prolapse after pelvic floor surgery. *Eur J Obstet Gynecol Reprod Biol*. 2010;153:220–3.
8. Dietz HP, Chantarasorn V, Shek KL. Levator avulsion is a risk factor for cystocele recurrence. *Ultrasound Obstet Gynecol*. 2010;36:76–80.
9. Wong V, Shek K, Rane A, Goh J, Krause H, Dietz H. Is levator avulsion a predictor of cystocele recurrence following anterior vaginal mesh placement? *Ultrasound Obstet Gynecol*. 2013;42:230–4.
10. Friedman T, Eslick GD, Dietz HP. Risk factors for prolapse recurrence: systematic review and meta-analysis. *Int Urogynecol J*. 2017. <https://doi.org/10.1007/s00192-017-3475-4>.
11. Rodrigo N, Wong V, Shek KL, Martin A, Dietz HP. The use of 3-dimensional ultrasound of the pelvic floor to predict recurrence risk after pelvic reconstructive surgery. *Aust N Z J Obstet Gynaecol*. 2014;54:206–11.
12. Kearney R, Miller J, Ashton-Miller J, Delancey J. Obstetric factors associated with levator ani muscle injury after vaginal birth. *Obstet Gynecol*. 2006;107:144–9.
13. Dietz H, Lanzarone V. Levator trauma after vaginal delivery. *Obstet Gynecol*. 2005;106:707–12.

14. Dietz H, Simpson J. Levator trauma is associated with pelvic organ prolapse. *Br J Obstet Gynaecol*. 2008;115:979–84.
15. DeLancey J, Morgan D, Fenner D, Kearney R, Guire K, Miller J, et al. Comparison of levator ani muscle defects and function in women with and without pelvic organ prolapse. *Obstet Gynecol*. 2007;109:295–302.
16. Shek K, Dietz H. Intrapartum risk factors of levator trauma. *Br J Obstet Gynaecol*. 2010;117:1485–92. <https://doi.org/10.1111/j.1471-0528.2010.02704.x>.
17. Shek K, Chantarasorn V, Langer S, Dietz H. Does levator trauma ‘heal’? *Ultrasound Obstet Gynecol*. 2012;40:570–5.
18. Rosenblatt P. Trans-obturator post-anal sling (TOPAS) procedure for fecal incontinence. *J Minim Invasive Gynecol*. 2007;14:S152.
19. Gerges B, Atan IK, Shek K, Dietz H. How to determine “ballooning” of the levator hiatus on clinical examination: a retrospective observational study. *Int Urogynecol J*. 2013;24:1933–7.
20. Dietz H. Ultrasound imaging of the pelvic floor. Part II: three-dimensional or volume imaging. *Ultrasound Obstet Gynecol*. 2004;23:615–25.
21. Dietz H. Ultrasound imaging of the pelvic floor: part 1: 2D aspects. *Ultrasound Obstet Gynecol*. 2004;23:80–92.
22. Dietz HP, Wong V, Shek KL. A simplified method for determining hiatal biometry. *Aust N Z J Obstet Gynaecol*. 2011;51:540–3.
23. Dietz H, Bernardo M, Kirby A, Shek K. Minimal criteria for the diagnosis of avulsion of the puborectalis muscle by tomographic ultrasound. *Int Urogynecol J*. 2011;22:699–704.
24. Dietz H, Abbu A, Shek K. The Levator urethral gap measurement: a more objective means of determining levator avulsion? *Ultrasound Obstet Gynecol*. 2008;32:941–5.
25. Zacharin RF, Hamilton NT. Pulsion enterocele: long-term results of an abdominoperineal technique. *Obstet Gynecol*. 1980;55:141–8.
26. Mellgren A, Zutshi M, Lucente VR, Culligan P, Fenner DE, Chern H, et al. A posterior anal sling for fecal incontinence: results of a 152-patient prospective multicenter study. *Am J Obstet Gynecol*. 2016;214:349. e341–8.
27. Barber MD. Symptoms and outcome measures of pelvic organ prolapse. *Clin Obstet Gynecol*. 2005;48:648–61.

Publisher’s note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.