



## Special article

# Pelvic reconstruction after abdominoperineal resection of the rectum

Carlos Moreno-Sanz,\* Marina Manzanera-Díaz, Mikael Clerveus, F. Javier Cortina-Oliva, Julián de Pedro-Conal, Joaquín Picazo-Yeste

Servicio de Cirugía, Hospital General La Mancha Centro, Alcázar de San Juan, Ciudad Real, Spain

## ARTICLE INFORMATION

## Article history:

Received August 31, 2010

Accepted October 5, 2010

## Keywords:

Abdominoperineal resection

Rectal cancer

Pelvis

Pelvic floor

Perineum

Reconstruction

## A B S T R A C T

Despite the advances in the treatment of cancer of the rectum and the expansion of the multimodal therapeutic technique, abdominoperineal resection (APR) still needs to be performed as radical treatment in 20%-30% of cases.

APR of the rectum involves a significant morbidity, including intestinal obstruction and wound complications, with radiotherapy-induced enteritis being able to develop in 15% of cases subjected to post-operative radiotherapy. Furthermore, with the aim of improving local oncology results, an extended APR is recommended; a technique that requires a perineal reconstruction technique that allows a tension free closure in a previously radiated tissue and may prevent perineal hernias developing.

The objective of this article is to review pelvic and perineal repair methods after APR due to cancer, with special attention to the new prosthetic repair techniques.

© 2010 AEC. Published by Elsevier España, S.L. All rights reserved.

## Reconstrucción pélvica tras amputación abdominoperineal del recto

## R E S U M E N

A pesar de los avances en el tratamiento del cáncer de recto y la expansión del abordaje terapéutico multimodal, todavía es necesaria la realización de una amputación abdominoperineal (AAP) como tratamiento radical en el 20-30% de los casos.

La AAP del recto está gravada con una importante morbilidad, destacando la obstrucción intestinal y las complicaciones de la herida, pudiendo desarrollarse una enteritis rádica en el 15% de los casos sometidos a radioterapia postoperatoria. Además, con el fin de mejorar los resultados oncológicos a nivel local, se recomienda la realización de una AAP ampliada, técnica que precisa de un procedimiento de reconstrucción perineal que permita un cierre sin tensión en un tejido previamente radiado y prevenga el desarrollo de hernias perineales.

El objetivo de este trabajo es revisar los métodos de reparación pélvica y perineal tras la AAP por cáncer, con especial atención a las nuevas técnicas de reparación protésica.

© 2010 AEC. Publicado por Elsevier España, S.L. Todos los derechos reservados.

## Palabras clave:

Resección abdominoperineal

Cáncer de recto

Pelvis

Suelo pélvico

Periné

Reconstrucción

\*Corresponding author.

E-mail address: cmsurgery@hotmail.com (C. Moreno-Sanz).

## Introduction

Colorectal cancer is the most common cancer in both sexes in Spain. Twenty-five thousand and six hundred cases are diagnosed each year, and one third of them are located in the rectum.<sup>1</sup> Despite advances in the treatment of rectal cancer and the expansion of the multimodal therapeutic approach, it is still necessary to perform an abdominoperineal resection (APR) as a radical treatment in 20%-30% of cases.<sup>2,3</sup>

APR of the rectum is burdened with significant morbidity, especially intestinal obstruction<sup>4,5</sup> and perineal wound complications (delayed healing, dehiscence, sinus and perineal hernia).<sup>6</sup>

Obstruction of the pelvis by the small intestine after surgery is associated with an intestinal obstruction incidence of 8%-19%,<sup>4,5</sup> with radiation enteritis developing in 15% of patients undergoing postoperative radiotherapy.<sup>7,8</sup> Half (50%) of these patients requires surgical treatment for complications, which has a morbidity of 50% and mortality of 15%.<sup>7,8</sup>

To improve cancer outcome at local level, a cylindrical or extended APR is recommended.<sup>9,10</sup> This is a technique that often requires perineal reconstruction to allow tension-free closure on previously irradiated tissue<sup>11</sup> and prevent perineal hernias from developing.<sup>12</sup>

The aim of this study was to critically analyse the different pelvic and perineal repair techniques after APR due to cancer, with special attention given to new prosthetic repair techniques.

## Pelvic partitioning methods

Postoperative fixation of small bowel loops in an operated pelvis is a risk factor for developing an adhesive small bowel obstruction. In addition, the lack of mobility of the intestine resulting from this procedure increases exposure to postoperative radiotherapy and, consequently, the risk of developing radiation enteritis.<sup>7</sup>

Several strategies have been designed for medical treatment and prevention of the effects of radiotherapy, with disappointing results. Bowel rest, the use of radioprotective, anti-diarrhoea and probiotic agents, hyperbaric oxygen, endoscopic therapy and intensity modulated radiation therapy provide inconsistent results and are, in many cases, symptomatic therapies that do not offer a definitive solution.<sup>13</sup> Therefore, surgical techniques that prevent obstruction and fixation of the bowel to the pelvis (pelvic partitioning) are one of the main tools available for preventing these complications.

Pelvic partition can be performed by autologous or prosthetic tissue. Primary suture of the pelvic peritoneum or reperitonealisation is a common technique in pelvic partition.<sup>14</sup> To prevent peritoneal closure under tension, the uterus, bladder and posterior aponeurosis of the abdominal rectus muscle have been used.<sup>15,16</sup> Despite its simplicity, tissue is under tension during closure and the risk of reperitonealisation disruption is high, and fixation of the bowel to the pelvis and its consequences are not definitely

prevented. Thus, Chen et al<sup>16</sup> reported a 12% incidence of post-radiotherapy enteritis with this technique, which is close to the accepted overall incidence of 15% for this complication.<sup>7</sup>

Use of the greater omentum is the most widely used pelvic partitioning method. It is used as a pedicle flap over the left gastroepiploic vessels, and the final end is sutured to the pelvic parietal peritoneum, perineal fat or is abandoned in the pelvis.<sup>17-27</sup> Interestingly, most of these studies only analysed perineal wound complications, not reporting the incidence of intestinal obstruction and post-radiotherapy enteritis. Only Russ et al,<sup>19</sup> in a retrospective study of 24 cases, subjectively mentioned that tolerance to radiotherapy after pelvic occlusion with greater omentum is improved.

Lastly, performing an omentopexy is also possible using the omentum as a "hammock", suturing its free edges to the sacral promontory, anterior abdominal wall and serosa of the colon.<sup>28,29</sup> While both series had positive results, those submitted by Choi and Lee<sup>29</sup> were particularly significant. This was a prospective, non-randomised study which found a significant difference when comparing chronic intestinal toxicity after radiotherapy in patients with omentopexy (12%) against a control group (40%).

Despite the widespread use of autologous tissue in pelvic partition, and especially the greater omentum, there is no solid evidence favouring the use of one method over another. Since it is difficult to propose a recommendation in the light of available studies, the absence or size of the omentum, the chances of suturing the pelvic peritoneum without tension, laparoscopy use and team preferences are therefore the factors determining the choice of technique.

If native tissue cannot be used for pelvic partition, alternative techniques have been proposed, such as pelvic occlusion by breast prosthesis,<sup>30</sup> synthetic spacers<sup>31</sup> and tissue expanders.<sup>32-34</sup> Pelvic occlusion with a prosthetic material prevents the bowel from adhering to other tissues and exposes it to the radiation area, thereby reducing the complications associated with radiotherapy. However, these techniques require re-operation to remove the prosthesis and are associated with significant morbidity (infection, fistula, vascular erosion), therefore, they are not in widespread use.<sup>34,35</sup>

Lastly, another pelvic partition prosthetic option is the use of a mesh (Table 1). The first description of this technique was made by Deveraux et al,<sup>36</sup> who used a polyglycolic acid mesh as a sling, preventing intestinal material from falling towards the pelvis. Subsequently, several articles were published describing the use of the same technique,<sup>37-40</sup> other absorbable material<sup>41,42</sup> and even non-absorbable prosthesis,<sup>43</sup> which proved their effectiveness in preventing intestinal obstruction due to pelvic adhesions and radiation enteritis.<sup>36,37,39</sup> However, inserting mesh involves longer operating times, postoperative ileus development<sup>7</sup> and complications with the mesh, such as obstruction,<sup>36,37</sup> intestinal fistula,<sup>36</sup> pelvic abscess,<sup>36,40</sup> hernia of the loops between the pelvis and the mesh<sup>37</sup> and deep vein thrombosis of the lower limbs.<sup>40</sup> However, it has been suggested that these techniques should be used despite these complications, as their appearance is incidental and many of them can be

**Table 1 – Pelvic partitioning using mesh**

	No.	Material	Study	Morbidity
Devereux et al <sup>36</sup>	60	Polyglycolic acid	Retrospective	–
Dashmahapatra et al <sup>37</sup>	45	Polyglycolic acid/polyglactin	Retrospective	Intestinal obstruction
Sener et al <sup>38</sup>	8	Polyglycolic acid	Retrospective	Obstruction, abscess, herniation
Rodier et al <sup>39</sup>	60	Polyglycolic acid	Multicentre	–
Beitler et al <sup>40</sup>	20	Polyglycolic acid	Retrospective	Abscess, DVT LL, wound complications
Kusunoki et al <sup>41</sup>	3	Polyglactin+Seprafilm	Retrospective	–
Waddell et al <sup>42</sup>	12	Polyglycolic acid/polyglactin	Prospective	–
Cui et al <sup>43</sup>	30	PTFE	Prospective	–

DVT LL indicates deep vein thrombosis of the lower limbs.

prevented by careful surgical technique.<sup>7</sup> Recently, Cui et al<sup>43</sup> submitted the results of a randomised prospective study on an ePTFE prosthesis partitioning method, using patients with conventional reperiitonealisation as a control group. The patients using ePTFE showed no episodes of intestinal obstruction after a mean of 18 months, with excellent results in postoperative morbidity, resolution of postoperative ileus and discharge from hospital. Although experience with this technique is limited, in view of the results and the emergence of new prosthetic material with excellent laparotomic and laparoscopic handling, good behaviour in contact with hollow viscera and excellent tolerance to infection, the use of mesh as a pelvic partitioning method after APR is very attractive.

### Perineal reconstruction techniques

Another problem after completion of an APR is the need for reconstruction of the pelvic floor, which is an especially important procedure after performing a cylindrical or extended APR. The high rate of infection and perineal wound dehiscence after primary closure is a major problem (25%-60%), whose incidence increases after radiotherapy.<sup>6,11</sup> In addition, according to the literature, there is a 3.5% risk of developing perineal hernia.<sup>6,12</sup>

Traditionally, large perineal defects are treated with myocutaneous flaps of rectus abdominis, gluteus and gracilis muscles.<sup>9,44-51</sup>

The flap of rectus abdominis muscle has been widely used because it provides a significant area of skin tissue to occlude the right pelvis and reach the surface of the perineum, with excellent results.<sup>46-48,50</sup> Recently, Lefevre et al<sup>48</sup> published the results obtained with this muscle section in a retrospective study comparing the results obtained from the rectus abdominis muscle flap and omentoplasty. Patients with the flap reconstruction showed a significant decrease in healing time of the perineum, perineal wound complications and a lack of hernias in this location. Finally, the incidence of eventration in patients treated with this reconstruction technique did not exceed the control group (7% vs 9.6%),<sup>48</sup> even though one of the most criticised aspects of the muscular flap is the incidence of abdominal wound

complications.<sup>51</sup> This complication and the difficulty in the positioning of stomata are the most controversial aspects of using the flap of rectus abdominis muscle.<sup>51</sup>

There is less experience with the gracilis muscle flap. It provides a smaller graft and seems to draw a significant number of local complications (abscess, necrosis).<sup>45</sup>

Lastly, although there are previous references,<sup>44</sup> publication of the experience of Holm et al<sup>9</sup> has reignited interest in the use of gluteal muscle flaps as a repair technique.<sup>51</sup> These techniques provide a significant amount of tissue, with a large and easily mobilised skin surface and few complications.<sup>9,51</sup>

Although the results obtained with the muscle flaps have fewer perineal wound complications, all are technically complex and may require other specialists, long surgical times, long bed rest and a risk of necrosis of the flap.<sup>9,44</sup> However, the use of the myocutaneous flap is still the most frequently used technique for perineal reconstruction following an extended APR.

The recent development of new prosthetic material has led to different types of absorbable biological prosthesis being proposed.<sup>52-54</sup>

Improved tissue regeneration, resistance to infection, tolerance and handling make these prostheses attractive for this type of reconstruction.<sup>55,56</sup> Although good results are reported, there is little experience with this type of repair.<sup>52-54</sup> However, morbidity is frequent (seroma in 6%-26%<sup>52-54</sup> and perineal pain in 33%<sup>53,54</sup>), although clinically insignificant.

### Conclusions

Despite advances in the treatment of rectal cancer and the expansion of the multimodal therapeutic approach, APR is still a required in 30% of cases.

Pelvic partitioning methods are necessary to prevent morbidity resulting from the obstruction and fixation of the bowel to the pelvis after APP, mainly in those cases receiving postoperative radiotherapy.

Although there are numerous pelvic partitioning methods described, the use of the greater omentum to occlude the pelvis is still the most frequently used option. In patients with an absence or a small greater omentum, the use of mesh

may be a good alternative, although there is insufficient experience to recommend its use routinely.

In patients subjected to an extended APR, perineal reconstruction has to be performed via the development of myocutaneous flaps, mainly dependent on the rectus abdominis muscle or gluteus maximus. However, the use of a mesh can also play an important role in this type of repair due to its technical complexity and associated morbidity.

Lastly, although the use of a mesh for pelvic partitioning and perineal reconstruction of the rectum after APR is simple and effective, there is little experience in this respect. Studies to clarify indications, the choice of appropriate material and technical aspects in relation to their placement are required.

## Conflict of interest

The authors affirm they have no conflict of interest.

## REFERENCES

- López-Abente G, Pollán M, Aragonés N, Pérez Gómez B, Hernández Barrera V, Lope V, et al. Situación del cáncer en España: incidencia. *An Sist San Navar*. 2004;27:165-73.
- Morris E, Quirke P, Thomas JD, Fairley L, Cottier B, Forman D. Unacceptable variation in abdominoperineal excision rates for rectal cancer: time to intervene? *Gut*. 2008;57:1690-7.
- Pera M, Pascual M. Quality standards in rectal cancer surgery. *Gastroenterol Hepatol*. 2005;28:417-25.
- Pollard CW, Nivatvongs S, Rojanasakul A, Ilstrup D.M. Carcinoma of the rectum. Profiles of intraoperative and early postoperative complications. *Dis Colon Rectum*. 1998;37:866-74.
- O'Brien DP, Senagore A, Merlino J, Brady K, Delaney C. Predictors and outcome of readmission after laparoscopic intestinal surgery. *World J Surg*. 2007;31:2430-5.
- El Gazzaz G, Kiran RP, Lavery I. Wound complications in rectal cancer patients undergoing primary closure of the perineal wound after abdominoperineal resection. *Dis Colon Rectum*. 2009;52:1962-6.
- Waddell BE, Rodriguez-Bigas MA, Lee RJ, Weber TK, Petrelli NJ. Prevention of chronic radiation enteritis. *J Am Coll Surg*. 1999;189:611-24.
- Regimbeau JM, Panis Y, Gouzi JL, Fagniez PL. Operative and long term results after surgery for chronic radiation enteritis. *Am J Surg*. 2001;182:237-42.
- Holm T, Ljung A, Häggmark T, Jurell G, Lagergren J. Extended abdominoperineal resection with gluteus maximus flap reconstruction of the pelvic floor for rectal cancer. *Br J Surg*. 2007;94:232-8.
- West NP, Finan PJ, Anderin C, Lindholm T, Holm T, Quirke P. Evidence of the oncologic superiority of cylindrical abdominoperineal excision for low rectal cancer. *J Clin Oncol*. 2008;21:3617-22.
- Bullard KM, Trudel JL, Baxter NN, Rothenberger DA. Primary perineal wound closure after preoperative radiotherapy and abdominoperineal resection has a high incidence of wound failure. *Dis Colon Rectum*. 2005;48:438-43.
- Aboian E, Winter DC, Metcalf DR, Wolff BG. Perineal hernia after proctectomy: prevalence, risks, and management. *Dis Colon Rectum*. 2006;49:1564-8.
- Theis VS, Sripadam R, Ramani V, Lal S. Chronic radiation enteritis. *Clin Oncol*. 2010;22:70-83.
- Druzijanić N, Perko Z, Srsen D, Pogorelić Z, Schwarz D, Jurčić J. Pelvic peritonization after laparoscopic abdominoperineal resection for low-rectal carcinoma treatment: surgical technique. *Hepatogastroenterology*. 2009;56:1028-31.
- Freund H, Gunderson L, Krause R, Fischer JE. Prevention of radiation enteritis after abdominoperineal resection and radiotherapy. *Surg Gynecol Obstet*. 1979;149:206-8.
- Chen JS, ChangChien CR, Wang JY, Fan HA. Pelvic peritoneal reconstruction to prevent radiation enteritis in rectal carcinoma. *Dis Colon Rectum*. 1992;35:897-901.
- Ruckley CV, Smith AN, Balfour TW. Perineal closure by omental graft. *Surg Gynecol Obstet*. 1970;131:300-2.
- Page CP, Carlton PK, Becker DW. Closure of the pelvic and perineal wounds after removal of the rectum and anus. *Dis Colon Rectum*. 1980;23:2-9.
- Russ JE, Smoron GL, Gagnon JD. Omental transposition flap in colorectal carcinoma: adjunctive use in prevention and treatment of radiation complications. *Int J Radiat Oncol Biol Phys*. 1984;10:55-62.
- Moreaux J, Horiot A, Barrat F, Mabilie J. Obliteration of the pelvic space with pedicled omentum after excision of the rectum for cancer. *Am J Surg*. 1984;148:640-4.
- Smith SR, Swift I, Gompertz H, Baker WN. Abdominoperineal and anterior resection of the rectum with retrocolic omentoplasty and no drainage. *Br J Surg*. 1988;75:1012-5.
- Poston GJ, Smith SR, Baker WN. Retrocolic pelvic omentoplasty in abdominoperineal excision of the rectum. *Ann R Coll Surg Engl*. 1991;73:229-32.
- John H, Buchmann P. Improved perineal wound healing with the omental pedicle graft after rectal excision. *Int J Colorectal Dis*. 1991;6:193-6.
- Rice ML, Hay AM, Hurlow RH. Omentoplasty in abdominoperineal resection of the rectum. *ANZ J Surg*. 1992;62:147-9.
- Hay JM, Fingerhut A, Paquet JC, Flamant Y. Management of the pelvic space with or without omentoplasty after abdominoperineal resection for carcinoma of the rectum: A prospective multicenter study. The French Association for Surgical Research. *Eur J Surg*. 1997;163:199-206.
- De Broux E, Parc Y, Rondelli F, Dehni N, Turet E, Parc R. Sutured perineal omentoplasty after abdominoperineal resection for adenocarcinoma of the lower rectum. *Dis Colon Rectum*. 2005;48:476-81.
- Nilsson PJ. Omentoplasty in abdominoperineal resection: a review of the literature using a systematic approach. *Dis Colon Rectum*. 2006;49:1354-61.
- Lechner P, Cesnik H. Abdominopelvic omentopexy: preparatory procedure for radiotherapy in rectal cancer. *Dis Colon Rectum*. 1992;35:1157-60.
- Choi HJ, Lee HS. Effect of omental pedicle hammock in protection against radiation-induced enteropathy in patients with rectal cancer. *Dis Colon Rectum*. 1995;38:276-80.
- Tuech JJ, Chaudron V, Thoma V, Ollier JC, Tasseti V, Duval D, et al. Prevention of radiation enteritis by intrapelvic breast prosthesis. *Eur J Surg Oncol*. 2004;30:900-4.
- Dürig M, Steenblock U, Heberer M, Harder F. Prevention of radiation injuries to the small intestine. *Surg Gynecol Obstet*. 1984;159:162-3.
- Hoffman JP, Sigurdson ER, Eisenberg BL. Use of saline-filled tissue expanders to protect the small bowel from radiation. *Oncology*. 1998;12:51-4.

33. Angster K, Shridharani SM, Rad AN, Ahuja N, Rosson GD. Intraabdominal tissue expanders to prevent radiation enteritis: preliminary report. *Plast Reconstr Surg*. 2010;125:177-9.
34. Hoffman JP, Lanciano R, Carp NZ, Merrick MA, Rosenblum NG, Hogan WM, et al. Morbidity after intraperitoneal insertion of saline-filled tissue expanders for small bowel exclusion from radiotherapy treatment fields: a prospective four year experience with 34 patients. *Am Surg*. 1994;60:473-82.
35. Vetto JT, Culp SC, Smythe TB, Chang AE, Sindelar WF, Sugarbaker PH, et al. Iliac arterial-enteric fistulas occurring after pelvic irradiation. *Surgery*. 1987;101:643-7.
36. Devereux DF, Chandler JJ, Eisenstat T, Zinkin L. Efficacy of an absorbable mesh in keeping the small bowel out of the human pelvis following surgery. *Dis Colon Rectum*. 1988;31:17-21.
37. Sener SF, Imperato JP, Blum MD, Ignatoff JM, Soper TG, Winchester DP, et al. Technique and complications of reconstruction of the pelvic floor with polyglactin mesh. *Surg Gynecol Obstet*. 1989;168:475-80.
38. Dasmahapatra KS, Swaminathan AP. The use of a biodegradable mesh to prevent radiation-associated small-bowel injury. *Arch Surg*. 1991;126:366-9.
39. Rodier JF, Janser JC, Rodier D, Dauplat J, Kauffmann P, Le Bouedec G, et al. Prevention of radiation enteritis by an absorbable polyglycolic acid mesh sling. A 60-case multicentric study. *Cancer*. 1991;68:2545-9.
40. Beitler A, Rodriguez-Bigas MA, Weber TK, Lee RJ, Cuenca R, Petrelli NJ. Complications of absorbable pelvic mesh slings following surgery for rectal carcinoma. *Dis Colon Rectum*. 1997;40:1336-41.
41. Kusunoki M, Yanagi H, Shoji Y, Noda M, Ikeuchi H, Yamamura T. Reconstruction of the pelvic floor using absorbable mesh with a bioresorbable membrane (Seprafilm) after abdominoperineal rectal excision. *J Surg Oncol*. 1999;70:261-2.
42. Waddell BE, Lee RJ, Rodriguez-Bigas MA, Weber TK, Petrelli NJ. Absorbable mesh sling prevents radiation-induced bowel injury during "sandwich" chemoradiation for rectal cancer. *Arch Surg*. 2000;135:1212-7.
43. Cui J, Ma JP, Xiang J, Luo YX, Cai SR, Huang YH, et al. Prospective study of reconstructing pelvic floor with GORE-TEX Dual Mesh in abdominoperineal resection. *Chin Med J*. 2009;122:2138-41.
44. Baird WL, Hester TR, Nahai F, Bostwick J. Management of perineal wounds following abdominoperineal resection with inferior gluteal flaps. *Arch Surg*. 1990;125:1486-9.
45. Shibata D, Hyland W, Busse P, Kim HK, Sentovich SM, Steele G, et al. Immediate reconstruction of the perineal wound with gracilis muscle flaps following abdominoperineal resection and intraoperative radiation therapy for recurrent carcinoma of the rectum. *Ann Surg Oncol*. 1999;6:33-7.
46. Butler CE, Rodriguez-Bigas MA. Pelvic reconstruction after abdominoperineal resection: is it worthwhile? *Ann Surg Oncol*. 2005;12:91-4.
47. Chessin DB, Hartley J, Cohen AM, Mazumdar M, Cordeiro P, Disa J, et al. Rectus flap reconstruction decreases perineal wound complications after pelvic chemoradiation and surgery: a cohort study. *Ann Surg Oncol*. 2005;12:91-4.
48. Lefevre JH, Parc Y, Kernéis S, Shields C, Touboul E, Chaouat M, et al. Abdomino-perineal resection for anal cancer: impact of a vertical rectus abdominis myocutaneous flap on survival, recurrence, morbidity, and wound healing. *Ann Surg*. 2009;250:707-11.
49. Nisar PJ, Scott HJ. Myocutaneous flap reconstruction of the pelvis after abdominoperineal excision. *Colorectal Dis*. 2009;11:806-16.
50. Nelson RA, Butler CE. Surgical outcomes of VRAM versus thigh flaps for immediate reconstruction of pelvic and perineal cancer resection defects. *Plast Reconstr Surg*. 2009;123:175-83.
51. Boccola MA, Rozen WM, Ek EW, Teh BM, Croxford M, Grinsell D. Inferior gluteal artery myocutaneous island transposition flap reconstruction of irradiated perineal defects. *J Plast Reconstr Aesthet Surg*. 2010;63:1169-75.
52. Boereboom CL, Watson NF, Sivakumar R, Hurst NG, Speake WJ. Biological tissue graft for pelvic floor reconstruction after cylindrical abdominoperineal excision of the rectum and anal canal. *Tech Coloproctol*. 2009;13:257-8.
53. Wille-Jørgensen P, Pilsgaard B, Møller P. Reconstruction of the pelvic floor with a biological mesh after abdominoperineal excision for rectal cancer. *Int J Colorectal Dis*. 2009;24:323-5.
54. Han JG, Wang ZJ, Gao ZG, Xu HM, Yang ZH, Jin M.L. Pelvic floor reconstruction using human acellular dermal matrix after cylindrical abdominoperineal resection. *Dis Colon Rectum*. 2010;53:219-23.
55. Candage R, Jones K, Luchette FA, Sinacore JM, Vandevender D, Reed RL. Use of human acellular dermal matrix for hernia repair: friend or foe? *Surgery*. 2008;144:703-9.
56. Rosen MJ. Biologic mesh for abdominal wall reconstruction: a critical appraisal. *Am Surg*. 2010;76:1-6.