

Incisional hernia: Risk factors, incidence, pathogenesis, prevention and complications

Ismat M. Mutwali

Department of Surgery,
Faculty of Medicine, Medical and
Health Education Development
Centre, Alzaeim Alazhari University,
Khartoum, Bahri, Sudan

Abstract

Incisional hernia (IH) is one the most common postoperative complications of abdominal surgery. Its incidence remains high in spite of the great improvement in the techniques and suture materials used for closing the abdominal wall incisions. Many procedures and techniques were described for preventing and repairing IH, but up to date there is a lack of consensus regarding the best approach for preventing and repairing it. The aim of the present article is to review the risk factors, incidence, pathogenesis, prevention and complication of IH. A database search was performed using a combination of the search terms: IH, risk factors, incidence, pathogenesis, prevention, and complications. Some of the relevant reference lists were search manually to obtain more relevant literature.

Key words: Complications, incidence, incisional hernia, pathogenesis, prevention, risk factors

INTRODUCTION

Incisional hernia (IH) is defined by the European hernia society as “any abdominal wall gap with or without a bulge in the area of postoperative scar perceptible or palpable by clinical examination or imaging”.^[1] Development of IH can follow any type of surgical incision, whatever its site or size, even the incision of the laparoscope trocar can cause it. IH was reported as a complication of abdominal surgery since the early days of surgery, Greedy (1836) and Maydl (1886) reported repair of IH, Judd (1912) and Gibbon (1920) described the anatomical repair of IH, Kirschner (1910) introduced the autograft (fascia lat, skin) and heterograft (skin) for repairing IH.

The incidence of IH is still high, in spite of the great improvement in the techniques and suture materials

used for closing the abdominal wall incisions. Many procedures and techniques were described for preventing and repairing IH; using different suture materials, suture repair, prosthetic repair, combination of different techniques or laparoscope. In spite of the many efforts for reducing the incidence of IH, still there is a lack of consensus regarding the best approach for preventing and repairing IH, because most of them are followed by complications.^[2] IH represents a major surgical issue for surgeons of all specialties. The number of articles published and indexed in PubMed, about IH increased by 3.9-fold during the decades 1991–2000 and 2001–2010, indicating the importance of the issue of IH.^[3]

The aim of the present article is to review the risk factors, incidence, pathogenesis, prevention and complication of IH in the first part. The management of the IH and its complication will be reviewed in a separate article. A database search was performed on midline PubMed and Cocharane database, using a combination of the search terms: IH, risk factors, incidence, pathogenesis, prevention and complications. Some of the relevant reference lists were also searched manually to obtain more relevant literature.

Access this article online

Quick Response Code:



Website:
www.sudanmedicalmonitor.org

DOI:
10.4103/1858-5000.146580

Address for correspondence:

Dr. Ismat M. Mutwali, Alzaeim Alazhari University, P O Box 1432, Khartoum, Bahri 13311, Sudan. E-mail: ismatwally@yahoo.ca

RISK FACTORS OF INCISIONAL HERNIA

The development of IH is associated with a number of risk factors, which may be related to patient, nature of the primary surgery and biological factors. Table 1 shows the common general risk factors for the development of IH.

PATIENT`S RELATED RISK FACTORS

The old age and male gender are considered as risk factors because wound healing is delayed and collagen synthesis decreased,^[4,7] beside the fact that the old age is the age of chronic diseases and malignancies. Obesity, expressed as body mass index (BMI) is a major risk factor of IH.^[6,8-12] A BMI > 24.4 kg/m² is considered as one of the predicting factors for developing IH, at 6 months after midline laparotomy.^[9] Co-morbidities: Diabetes mellitus, jaundice, malignancies, chronic lung diseases, prostatism, chronic constipations, as well as heavy lifting are well known risk factors for hernia development by increasing the intra-abdominal pressure, delaying healing and delaying collagen synthesis.^[8,13-16] Immuno-supression in organ transplant patients increases the rate of wound infection, wound dehiscence and IH.^[17] Steroid therapy for certain chronic diseases or as a bolus therapy for immuno suppression in organ transplant patients and chemotherapy are risk factors of IH.^[15,16,18]

SURGERY RELATED RISK FACTORS

Emergency surgery increases the risk of IH as a result of postoperative complications, inadequate patient preparation, use of drains and the midline approach in

the emergency operations.^[15] The nature of the surgical operation; operations in which there may be wound contamination (bowel resection or secondary peritonitis), surgery for malignant tumours, abdominal aortic aneurysm, stoma closure, major abdominal surgeries and operations followed by open abdomen treatment with negative pressure and delayed primary wound closure, are all risk factors for development of IH.^[15,19-24] Selection of the site incision, suture materials and the technique of closure of incision are important factors. Midline abdominal incision has a higher risk for developing IH compared to transverse and oblique incisions (11%, 4.7% and 0.7% respectively)^[4,25] The technique of closing the abdominal fascia and the suture material used play a major role in developing IH.^[7,15,26] Re-laparotomy is a strong risk factor.^[5] Furthermore factors related to the surgeon experience, long operation time and increased blood loss increase the risk of IH.^[7,10] Wound infection and wound dehiscence are major risk factors for IH. This risk is more prominent after burst abdomen with evisceration.^[4,24-28] The 10-year cumulative risk for developing IH after wound dehiscence is 78% regardless of suture material and technique used.^[29] Murray (2911) reported an increase of IH by 1.9-fold after surgical site infection. Operation on the previously infected or the relatively avascular scar tissue increases the risk of IH.^[5,29,30]

BIOLOGICAL RISK FACTORS

The unchanged incidence of IH over the last decades can only be explained by the presence of biological factors that are individual dependent. These factors include: Synthesis of different types of collagen, enzymes defects, smoking and some nutritional deficiencies.^[31] Defective collagen metabolism and synthesis is one of the major factors involved in the development of IH. Patients with IH have a reduced ratio of collagen I: Collagen III as well as a reduced ratio of matrix metalloproteinase 1 (MMP1) to MMP2. These reductions in the synthesis of different types of collagen and enzymes play a role in the development of IH. Biological elements like copper and zinc are important for the integrity of collagen because they are necessary for the synthesis of the enzyme Laysyl oxidase which contribute in the integrity of the collagen molecule.^[32-34] The presence of other biological factors (plasminogen activator inhibitor, urokinase plasminogen activator inhibitor) in the scar tissue may contribute in the development of IH.^[34] Smoking is a well-known risk factor for hernia development.^[5,10,15,16,31,35-37] Smokers have four folds higher risk than nonsmokers. Smoking can cause a peripheral tissue hypoxia which increases the risk of wound infection by reducing the oxidative killing mechanism of the neutrophils.^[5] Preoperative cessation of smoking reduces

Table 1: Risk factors of incisional hernia

Patient related factors
Age: More than 60 years
Gender: Male
Obesity: BMI >25 kg/m ²
Co-morbidities: Diabetes mellitus, chronic lung diseases, obstructive jaundice. Immuno suppression in organ transplant patients, chemotherapy and steroid therapy
Surgery related factors
Emergency operations, bowel surgery, abdominal aortic aneurism, stoma closure, operations for peritonitis, re-laparotomy
Technique and suture material used for closure of the abdominal incisions
Wound infection, long operating time, increased blood loss, surgeon experience
Biological factors
Collagen and metalloproteinase synthesis
Smoking
Nutritional deficiencies

BMI: Body mass index

the rate of surgical site infection, but not the rate of wound failure and hernia development.^[37]

INCIDENCE OF INCISIONAL HERNIA

Incisional hernia is one of the commonest complications of abdominal surgery. Its incidence is dependent on the acting risk factors. IH can develop at different times from surgery, but 90% of IHs occur during the first 3-year of surgery.^[38] It varies between 11% and 20% in uncomplicated wounds.^[4,8,26,38] The incidence is higher in the presence of specific risk factors and in special situations. IH develops more common following midline incisions than other incisions.^[4,8,26,38] The incidence of IH after McBurney's incision in female is 0.7%.^[25] Continuous sutures using a slowly absorbable or nonabsorbable mono-filament suture material reduces the incidence of IH. Using good bite and short interval between stitches to respect the ratio of suture length (SL) to wound length (WL) >4 decreases the risk of IH.^[13,39-43] The use of nonabsorbable suture material for closing the midline laparotomy incisions reduces the incidence of IH.^[44] IH is more prevalent following open resection than laparoscopic resection of the colon (18% vs. 7%).^[45] In patients with high BMI the incidence of IH increases significantly.^[11,20,22,46] The incidence of IH is increased after wound dehiscence, treatment of the open abdomen, after aortic reconstructive surgery and surgery for secondary peritonitis and stoma closure.^[11,20,22,29,47]

PATHOGENESIS OF INCISIONAL HERNIA

Incisional hernia occurs when the tissue structure and function is disturbed over a previous surgical scar. Two main biological mechanisms are involved in the pathogenesis of IH: Primary fascial pathology and secondary wound failure over a surgical scar. The extra cellular molecular defect that develops after these two mechanisms leads to IH.^[35] Abnormal collagen metabolism, enzymes deficiency or excessive synthesis are the early mechanisms that are involved in the development of IH. Acquired collagen defect is related to smoking and nutritional deficiencies. The fascial pathology secondary to wound failure is due to formation of the scar tissue and to the defects in the function of the fibroblasts and collagen structure. Wound failure and loss of the normal healing process induces appearance of abnormal fibroblasts that leads to abnormal collagen, because fibroblasts are the main source of collagen synthesis.^[35] Straining during coughing, heavy lifting, abdominal distention and ascites can induces secondary changes on tissue fibroblasts. Wound ischemia due to intra operative shock, closure under undue tension or in the avascular scar tissue leads to defective tissue repair. Obesity

increases the intra-abdominal pressure, but the exact mechanism by which obesity causes IH is not well defined, a mechanical stress could be the cause.^[11,12] The consequences of the abnormal collagen metabolism are delayed, and defective collagen synthesis, and an increase in the activity of the protease enzymes at the level of the wound that increases collagen degradation. The end result is a reduction in type I and type III collagen, a decreased ratio of collagen I to collagen III. The reduction of the collagen synthesis and wound tensile strength increase the risk of the mechanical wound failure.^[35] Other factors that contribute to the quantitative and qualitative wound failure include: Inadequate hemostasis that results in hematoma formation with its mechanical disruption effect on the surgical wound, delayed or defective inflammatory response that results in wound contamination and hence prolongation of the transition to the proliferative phase of healing and delayed fibroblast response that in turn leads to delaying in synthesis of wound matrix. Following wound infection, multiplication of bacteria in the wound affects the process of healing which results in a decreased and defective collagen synthesis. This defective collagen synthesis leads to wound dehiscence and late IH development.^[5] Smoking apart from reducing the oxidative killing mechanism of neutrophils, it can also decrease collagen synthesis and produces a decrease in collagen I to collagen III ratio. Smoking also increase the degradation of the connective tissue as a consequence of enhancing the imbalance between protease activity and their inhibitors. Acute tissue hypoxia caused by smoking leads to tissue necrosis in the fragile tissues of the wound.^[47] The postulation that IH is developed as a result of multiple biological factors action is raised after the failure of reducing the incidence of IH by other nonbiological measures.^[5,32,33]

PREVENTION OF INCISIONAL HERNIA

There is no standardized intervention or procedure agreed upon for prevention of IH. Measurements that should be taken to reduce the incidence of IH include: General measures for reducing the postoperative complications, interventions or procedures used to prevent IH in high risk patients and measures related to the technique and selection of suture material used for closing abdominal wall incisions. Preoperative preparation by controlling the major risk factors reduces the risk of IH. Administration of preoperative appropriate antibiotics for all patients undergoing emergency or elective surgery where there is a risk of contamination and in high-risk patients is well known to reduce postoperative complication including IH. The appropriate approach and technique for closure of the abdominal incision in high-risk patients reduces the risk of IH. Postoperative control of pain, prevention of respiratory complications by respiratory training and

early mobilization, reducing the operative time, gentle manipulation of tissues and avoiding intra operative contamination are some of the general measures that reduces IH.^[41-44,47] The selection of suture material and the technique for closing laparotomy incisions plays a major role in prevention of IH.

There are some procedures and interventions, used for prevention and management of IH that played a major role in reducing the incidence of IH and its recurrence: These include: Technique and suture material selected for closure of the abdominal incisions; the use of prosthetic repair of IH; the introduction of minimally invasive surgery for treating IH and control of wound infection and wound dehiscence. Selection of a slowly absorbable or nonabsorbable mono filament suture material and increasing the ratio of SL to WL >4 significantly reduced the incidence of IH.^[13,28-44,48,49] The use of prosthetic material, synthetic or biologic, and the different surgical techniques for prevention of IH in high risk patients proved to be safe and effective in reducing the incidence of IH.^[50-53] The cumulative rate of recurrence of IH was reduced by using mesh for repairing IH.^[54] The introduction of the minimally invasive surgery in the sixties of the last century contributed in the reduction of the incidence of IH. Le Huu (2012) reported an incidence of 22% versus 0.7% for open versus laparoscopic surgery. Skipowth (2010) reported a 4–18% incidence after open colorectal resection and 7% for laparoscopic resection, whereas Liaguna (2010) found no reduction in the incidence following laparoscopic colectomy. Prevention of wound infection and wound dehiscence by using appropriate prophylactic antibiotics and suitable techniques is known to reduce the incidence of IH.^[26,47,46] Patients with previous wound infection have a 41% risk to develop re infection in subsequent surgery even

in the absence of clinical signs of infection. This high rate of infection can be reduced by prophylactic antibiotics.^[30]

Table 2 shows different techniques and suture materials used for closing abdominal incision in order to prevent IH. Continuous suturing using mono filament slowly absorbable or nonabsorbable suture material, combined with increasing the ratio of SL to WL >4 is the most effective method for reducing the incidence of IH.^[13,26,39,41,42,55] For high-risk patients, some procedures and intervention were used to reduce the incidence of IH. Table 3 shows different procedures used for prevention of IH and their results. A number of experimental interventional studies were conducted to evaluate their role in the prevention of IH. Injection of transforming growth factor beta 2 into the abdominal wall increases the production of collagen I and III reduced the incidence of IH in rats.^[56] Administration of transforming growth factor beta 2, basic fibroblast growth factor and inter leukine 1 beta reduces the incidence of IH in rats.^[56] Treating abdominal wall incisions with a sustained–release of basic fibroblast growth factor reduced the incidence of IH and its recurrence in rats model.^[57]

COMPLICATIONS OF INCISIONAL HERNIA

Untreated IH enlarges by time and makes repair difficult. IH can cause abdominal pain or discomfort, limitation of the daily activity and unsightly appearance. Complication of IH is not common, but can be very serious and even life-threatening. Intestinal obstruction, incarceration or strangulation and entero cutaneous fistula can develop. Skin ulceration spontaneous rupture can threaten the life of the patients with untreated IH.^[58-60]

Table 2: Techniques and suture material used for prevention of IH

Technique and suture	Results	Author and date
Continuous suture of midline incision using synthetic material	Good, reduced the rate of IH	Trimbes 1992
Increasing the SL: WL >4	Reduces the incidence of IH	Israelsson 1996, 2012
Increasing the SL: WL >4, using continuous technique and monofilament slowly absorbable suture	Decrease IH incidence and its recurrence	Jargon 2008
Continuous mattress suture+SL: WL >4	Superior to interrupted single sutures	Hoer 2002
Continuous suture versus interrupted suture+tension suture	6% versus 53% incidence of IH	Gislason 1990
Small suture using nonabsorbable material	Fewer postoperative complications and IH	Capella 2007
Continuous suture using slowly absorbable material	Optimal method for closure of abdominal incisions	Van't 2002
Using proline for closing midline incision in high risk patients	Effective, easy and reducing IH incidence	Murtaza 2010
Using small stitches continuous+increasing SL: WL >4	Reduces IH incidence	Millabourn 2011, Israelsson 2012
Continuous suturing using mono filament slowly absorbable suture material	Reduces incidence of IH	Albertstmeier 2012, Diener 2010
Small stitches sand continuous technique	Better results in prevention of IH	Rahbari 2009
Long stitches versus short stitches (big bite vs. small bite)	Big bite has higher incidence of IH (18% vs. 5.6%)	Millabourn 2011
Antibacterial braided suture material (fast or slow absorbable)	Does not increase the rate of IH	Justinger 2012

SL: Suture length, WL: Wound length, IH: Incisional hernia

Table 3: Some of the procedures and interventions used for prevention of IH

Procedure or intervention	Results	Author and date
Polygalactin mesh insertion for high risk patients	Does not decrease incidence of IH	Pans 1995
Using alloplastic mesh for reinforcement of abdominal closure	Reduces the rate of IH	Klinge 1997
Rectus banding	Good result and effective in long-term	Sham 2009
Rectus sheath relaxation incisions	Safe, reduces rate of wound dehiscence and IH	Maruhs 2005
Using a bio absorbable plug for prevention of trocar site IH	Simple feasible and effective	Moreno 2008
Sub fascial nonabsorbable mesh for midline incisions in high risk patient	Safe, effective and provide strengthening of wound	Elkhadrawy 2009
Using biologic mesh placement in high risk patients	Safe effective and reducing incidence from 17.7% to 2.3%	Liaguna 2011
Preperitoneal proline mesh placement in high risk patients	Safe and effective in preventing IH	Hidalgo 2011
Placement of proline mesh preperitoneal in high risk patients	Effective for reducing the rate of IH	Aborayia 2013

IH: Incisional hernia

ACKNOWLEDGMENT

The author acknowledges the valuable help of Dr. Awad Elkarem M H of the Department of Microbiology faculty of technical medicam sciences of Alzaeim Alazhari University.

REFERENCES

- Muysoms FE, Miserez M, Berrevoet F, Campanelli G, Champault GG, Chelala E, *et al.* Classification of primary and incisional abdominal wall hernias. *Hernia* 2009;13:407-14.
- Flum DR, Horvath K, Koepsell T. Have outcomes of incisional hernia repair improved with time? A population-based analysis. *Ann Surg* 2003;237:129-35.
- Kulacoglu H, Oztuna D. Growth and trends in publications about abdominal wall hernias and the impact of a specific journal on herniology: A bibliometric analysis. *Hernia* 2011;15:615-28.
- Le Huu Nho R, Mege D, Ouaiissi M, Sielezneff I, Sastre B. Incidence and prevention of ventral incisional hernia. *J Visc Surg* 2012;149 5 Suppl: e3-14.
- Sorensen LT, Hemmingsen UB, Kirkeby LT, Kallehave F, Jorgensen LN. Smoking is a risk factor for incisional hernia. *Arch Surg* 2005;140:119-23.
- Llaguna OH, Avgerinos DV, Lugo JZ, Matatov T, Abbadessa B, Martz JE, *et al.* Incidence and risk factors for the development of incisional hernia following elective laparoscopic versus open colon resections. *Am J Surg* 2010;200:265-9.
- Manninen MJ, Lavonius M, Perhoniemi VJ. Results of incisional hernia repair. A retrospective study of 172 unselected hernioplasties. *Eur J Surg* 1991;157:29-31.
- Sugerman HJ, Kellum JM Jr, Reines HD, DeMaria EJ, Newsome HH, Lowry JW. Greater risk of incisional hernia with morbidly obese than steroid-dependent patients and low recurrence with prefascial polypropylene mesh. *Am J Surg* 1996;171:80-4.
- Veljkovic R, Protic M, Gluhovic A, Potic Z, Milosevic Z, Stojadinovic A. Prospective clinical trial of factors predicting the early development of incisional hernia after midline laparotomy. *J Am Coll Surg* 2010;210:210-9.
- Murray BW, Cipher DJ, Pham T, Anthony T. The impact of surgical site infection on the development of incisional hernia and small bowel obstruction in colorectal surgery. *Am J Surg* 2011;202:558-60.
- Schreinemacher MH, Vijgen GH, Dagnelie PC, Bloemen JG, Huizinga BF, Bouvy ND. Incisional hernias in temporary stoma wounds: A cohort study. *Arch Surg* 2011;146:94-9.
- Lau B, Kim H, Haigh PI, Tejirian T. Obesity increases the odds of acquiring and incarcerating noninguinal abdominal wall hernias. *Am Surg* 2012;78:1118-21.
- Jargon D, Friebe V, Hopt UT, Obermaier R. Risk factors and prevention of incisional hernia – what is evidence-based? *Zentralbl Chir* 2008;133:453-7.
- Koivukangas V, Oikarinen A, Risteli J, Haukipuro K. Effect of jaundice and its resolution on wound re-epithelization, skin collagen synthesis, and serum collagen propeptide levels in patients with neoplastic pancreaticobiliary obstruction. *J Surg Res* 2005;124:237-43.
- Hesselink VJ, Luijendijk RW, de Wilt JH, Heide R, Jeekel J. An evaluation of risk factors in incisional hernia recurrence. *Surg Gynecol Obstet* 1993;176:228-34.
- Aboian E, Winter DC, Metcalf DR, Wolff BG. Perineal hernia after proctectomy: Prevalence, risks, and management. *Dis Colon Rectum* 2006;49:1564-8.
- Brewer MB, Rada EM, Milburn ML, Goldberg NH, Singh DP, Cooper M, *et al.* Human acellular dermal matrix for ventral hernia repair reduces morbidity in transplant patients. *Hernia* 2011;15:141-5.
- Janssen H, Lange R, Erhard J, Malagó M, Eigler FW, Broelsch CE. Causative factors, surgical treatment and outcome of incisional hernia after liver transplantation. *Br J Surg* 2002;89:1049-54.
- Takagi H, Sugimoto M, Kato T, Matsuno Y, Umamoto T. Postoperative incision hernia in patients with abdominal aortic aneurysm and aortoiliac occlusive disease: A systematic review. *Eur J Vasc Endovasc Surg* 2007;33:177-81.
- Moussavian MR, Schuld J, Dauer D, Justinger C, Kollmar O, Schilling MK, *et al.* Long term follow up for incisional hernia after severe secondary peritonitis-incidence and risk factors. *Am J Surg* 2010;200:229-34.
- Antoniou GA, Georgiadis GS, Antoniou SA, Grandrath FA, Giannoukas AD, Lazarides MK. Abdominal aortic aneurysm and abdominal wall hernia as manifestations of a connective tissue disorder. *J Vasc Surg* 2011;54:1175-81.
- Bhangu A, Nepogodiev D, Futaba K, West Midlands Research Collaborative. Systematic review and meta-analysis of the incidence of incisional hernia at the site of stoma closure. *World J Surg* 2012;36:973-83.
- Bensley RP, Schermerhorn ML, Hurks R, Sachs T, Boyd CA, O'Malley AJ, *et al.* Risk of late onset adhesion and incisional hernia repair after surgery. *Am J Surg* 2013;216:1159-67.e12.
- Brandl A, Laimer E, Perathoner A, Zitt M, Pratschke J, Kafka-Ritsch R. Incisional hernia rate after open abdomen treatment with negative pressure and delayed primary fascia closure. *Hernia* 2014;18:105-11.
- Beltrán MA, Cruces KS. Incisional hernia after McBurney incision: Retrospective case-control study of risk factors and surgical treatment. *World J Surg* 2008;32:596-601.
- Müller-Riemenschneider F, Roll S, Friedrich M, Zieren J, Reinhold T, von der Schulenburg JM, *et al.* Medical effectiveness and safety of conventional compared to laparoscopic incisional hernia repair: A systematic review. *Surg Endosc* 2007;21:2127-36.
- Song IH, Ha HK, Choi SG, Jeon BG, Kim MJ, Park KJ. Analysis of risk factors for the development of incisional and parastomal hernias in patients after colorectal surgery. *J Korean Soc Coloproctol* 2012;28:299-303.

Mutwali: Incisional hernia: Risk factors, incidence, pathogenesis, prevention and complications

28. Gislason H, Viste A. Closure of burst abdomen after major gastrointestinal operations – Comparison of different surgical techniques and later development of incisional hernia. *Eur J Surg* 1999;165:958-61.
29. Lamont PM, Ellis H. Incisional hernia in re-opened abdominal incisions: An overlooked risk factor. *Br J Surg* 1988;75:374-6.
30. Houck JP, Rypins EB, Sarfeh IJ, Juler GL, Shimoda KJ. Repair of incisional hernia. *Surg Gynecol Obstet* 1989;169:397-9.
31. Bellón JM, Durán HJ. Biological factors involved in the genesis of incisional hernia. *Cir Esp* 2008;83:3-7.
32. Ozdemir S, Ozis ES, Gulpinar K, Aydin SM, Eren AA, Demirtas S, *et al*. The value of copper and zinc levels in hernia formation. *Eur J Clin Invest* 2011;41:285-90.
33. Salameh JR, Talbott LM, May W, Gosheh B, Vig PJ, McDaniel DO. Role of biomarkers in incisional hernias. *Am Surg* 2007;73:561-7.
34. Rosch R, Binnebösel M, Junge K, Lynen-Jansen P, Mertens PR, Klinge U, *et al*. Analysis of c-myc, PAI-1 and uPAR in patients with incisional hernias. *Hernia* 2008;12:285-8.
35. Franz MG. The biology of hernia formation. *Surg Clin North Am* 2008;88:1-15.
36. Franz MG, Kuhn MA, Nguyen K, Wang X, Ko F, Wright TE, *et al*. Transforming growth factor beta (2) lowers the incidence of incisional hernias. *J Surg Res* 2001;97:109-16.
37. Sorensen LT. Wound healing and infection in surgery. The clinical impact of smoking and smoking cessation: A systematic review and meta-analysis. *Arch Surg* 2012;147:373-83.
38. Mudge M, Hughes LE. Incisional hernia: A 10 year prospective study of incidence and attitudes. *Br J Surg* 1985;72:70-1.
39. Israelsson LA, Jonsson T. Incisional hernia after midline laparotomy: A prospective study. *Eur J Surg* 1996;162:125-9.
40. Israelsson LA. The surgeon as a risk factor for complications of midline incisions. *Eur J Surg* 1998;164:353-9.
41. Israelsson LA, Millbourn D. Closing midline abdominal incisions. *Langenbecks Arch Surg* 2012;397:1201-7.
42. Millbourn D, Cengiz Y, Israelsson LA. Risk factors for wound complications in midline abdominal incisions related to the size of stitches. *Hernia* 2011;15:261-6.
43. van 't Riet M, Steyerberg EW, Nellensteyn J, Bonjer HJ, Jeekel J. Meta-analysis of techniques for closure of midline abdominal incisions. *Br J Surg* 2002;89:1350-6.
44. Murtaza B, Ali Khan N, Sharif MA, Malik IB, Mahmood A. Modified midline abdominal wound closure technique in complicated/high risk laparotomies. *J Coll Physicians Surg Pak* 2010;20:37-41.
45. Skipworth JR, Khan Y, Motson RW, Arulampalam TH, Engledow AH. Incisional hernia rates following laparoscopic colorectal resection. *Int J Surg* 2010;8:470-3.
46. van't RM, De Vos Van Steenwijk PJ, Bonjer HJ, Steyerberg EW, Jeekel J. Incisional hernia after repair of wound dehiscence: Incidence and risk factors. *Am Surg* 2004;70:281-6.
47. Justinger C, Slotta JE, Schilling MK. Incisional hernia after abdominal closure with slowly absorbable versus fast absorbable, antibacterial-coated sutures. *Surgery* 2012;151:398-403.
48. Albertsmeier M, Seiler CM, Fischer L, Baumann P, Hüsing J, Seidlmayer C, *et al*. Evaluation of the safety and efficacy of MonoMax® suture material for abdominal wall closure after primary midline laparotomy-a controlled prospective multicentre trial: ISSAAC [NCT005725079]. *Langenbecks Arch Surg* 2012;397:363-71.
49. Diener MK, Voss S, Jensen K, Büchler MW, Seiler CM. Elective midline laparotomy closure: The INLINE systematic review and meta-analysis. *Ann Surg* 2010;251:843-56.
50. Marwah S, Marwah N, Singh M, Kapoor A, Karwasra RK. Addition of rectus sheath relaxation incisions to emergency midline laparotomy for peritonitis to prevent fascial dehiscence. *World J Surg* 2005;29:235-9.
51. El-Khadrawy OH, Moussa G, Mansour O, Hashish MS. Prophylactic prosthetic reinforcement of midline abdominal incisions in high-risk patients. *Hernia* 2009;13:267-74.
52. Llaguna OH, Avgerinos DV, Nagda P, Elfant D, Leitman IM, Goodman E. Does prophylactic biologic mesh placement protect against the development of incisional hernia in high-risk patients? *World J Surg* 2011;35:1651-5.
53. Abo-Ryia MH, El-Khadrawy OH, Abd-Allah HS. Prophylactic preperitoneal mesh placement in open bariatric surgery: A guard against incisional hernia development. *Obes Surg* 2013;23:1571-4.
54. Luijendijk RW, Hop WC, van den Tol MP, de Lange DC, Braaksma MM, IJzermans JN, *et al*. A comparison of suture repair with mesh repair for incisional hernia. *N Engl J Med* 2000;343:392-8.
55. Rahbari NN, Knebel P, Diener MK, Seidlmayer C, Ridwelski K, Stöltzing H, *et al*. Current practice of abdominal wall closure in elective surgery-Is there any consensus? *BMC Surg* 2009;9:8.
56. Robson MC, Dubay DA, Wang X, Franz MG. Effect of cytokine growth factors on the prevention of acute wound failure. *Wound Repair Regen* 2004;12:38-43.
57. Dubay DA, Wang X, Kuhn MA, Robson MC, Franz MG. The prevention of incisional hernia formation using a delayed-release polymer of basic fibroblast growth factor. *Ann Surg* 2004;240:179-86.
58. Nieuwenhuizen J, Kleinrensink GJ, Hop WC, Jeekel J, Lange JF. Indications for incisional hernia repair: An international questionnaire among hernia surgeons. *Hernia* 2008;12:223-5.
59. Gupta RK, Sah S, Agrawal SC. Spontaneous rupture of incisional hernia: A rare cause of a life-threatening complication. *BMJ Case Rep* 2011;2011.
60. Rickert A, Kienle P, Kuthe A, Baumann P, Engemann R, Kuhlitz J, *et al*. A randomised, multi-centre, prospective, observer and patient blind study to evaluate a non-absorbable polypropylene mesh vs. a partly absorbable mesh in incisional hernia repair. *Langenbecks Arch Surg* 2012;397:1225-34.

How to cite this article: Mutwali IM. Incisional hernia: Risk factors, incidence, pathogenesis, prevention and complications. *Sudan Med Monit* 2014;9:81-6.

Source of Support: Nil. **Conflict of Interest:** None declared.