RQ: Do open pelvic injuries require a different antibiotic protocol?

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BACKGROUND:

Open Pelvic Fractures (OPF), by definition, constitute skeletal injuries to the pelvis when there is a direct communication of the fracture hematoma with a skin/anorectal/urogenital wound [1-3]. Although rare, these injuries are associated with an extremely high degree of mortality, sometimes as high as 50% [4-7]. There are two main reasons theorized for this- (i) Early mortality due to intractable bleeding and hemorrhagic shock secondary to an unstable pelvic fracture as well as extensive soft tissue injury; (ii) Delayed sequelae resulting from heavy contamination of the open wound which, in turn, leads to sepsis and multiple organ dysfunction syndrome (MODS) [6,8]. OPFs are the result of high energy blunt or penetrating trauma and are often associated with injuries to the hollow visceral contents of the pelvis such as urethra, bladder, genitalia, rectum, anal canal etc. Hence, these pose a distinct diagnostic as well as therapeutic challenge to trauma surgeons across the globe. A multi-disciplinary approach has been recommended for the management of these injuries [9,10]. However, despite the advent of Advanced Trauma Life Support (ATLS) protocols and advances in critical care medicine, residual mortality continues to be significantly high [1,7,11].

An important determinant of patient survival is the choice and duration of prophylactic antibiotic therapy. While literature has concise antimicrobial recommendations for open fractures in long bones, there are no clear-cut guidelines prescribed for OPFs.

DATA EXTRACTION TABLE:

S.no	Author, year of publication, Country	Study Design	Sample Size (add individually for each group if multiple groups compared)	Study population (Inclusion and exclusion criteria)	Groups compared	Results
1	Rothenberger et al [4]., 1978, United States of America	Retrospective observational study	Total - 604 Closed pelvic fractures – 582; Open pelvic fractures- 22	Inclusion: Closed and open fractures of the pelvis Exclusion: Avulsion and pathological fractures	Closed versus open pelvic fractures	<u>Open pelvic fractures:</u> 1. Average age- 34 (range, 10-75) years 2. Sex ratio- M: F was 14:8 3. Mode of injury- - Motorcycle accidents 4 (18%) - Pedestrian injuries 13 (59%) - Vehicular accidents 2(9%) - Penetrating gunshot wounds 3 (14%) 4. Mortality- 11 (50%) 5. Major vessel injury – 6 (27%) 6. Sciatic/ peroneal nerve injury – 2 (9%) 7. Wounds- - Vaginal lacerations 1 - Rectal lacerations 2 - Perineal wound 8 - Other skin lacerations 10 8. Urinary tract injuries- 5 (23%) 9. Sepsis- 8 (36%) - Died 4 - Survivors 4 10. Broad spectrum antibiotics <u>Open versus Closed fractures:</u> 1. Mortality – 11/22 (50%) versus 61/582 (10.5%) 2. Blood loss – 29.4 units*/patient versus 10 units/patient 3. Sepsis – 8/22 (36%) versus 1/582 (0.2%) *1 unit – 500ml

2.	Birolini et al [10]., 1990, Brazil	Retrospective observational study	Total - 48	Open pelviperineal trauma	Not applicable (NA)	1. Average age- 19 (range, 3-47) years 2. Sex ratio- M: F was 29:19 3. Mode of injury- - Motorcycle accidents 6 (12.5%) - Pedestrian injuries 37 (77%) - Motor vehicle injuries 3 (6.25%) - Pedestrian injuries (train) 1 (2%) - Fall 1 (2%) 4. Mortality- 19 (39.6%) 5. Major vessel injury (Iliac vessels 4 + Inferior vena cava 2)-6 (12.5%) 6. Small bowel injuries -2 (4.2%) 7. Anorectal injuries – 7 (14.6%) 8. Urogenital injuries- - Urethra 11 - Vagina 11 - Scrotum 8 - Bladder 6 - Vulva 6 - Testis 5 - Penis 5 9. Sepsis – 12 (25%) (All died) 10. Microbial flora isolated – 31 (64.6%) - *S. aureus* 22 - *E. coli* 8 - *K. pneumoniae* 12 - *Acinetobacter* 3 - *P. aeruginosa* 9 - *P. mirabilis* 1 - *Candida sp.* 1 11. Broad spectrum antibiotic – Crystalline Penicillin + Chloramphenicol + Gentamicin initially followed by culture specific antibiotics
3.	Mosheiff et al [3].,1999, Israel	Retrospective observational study	Total - 15	Open pelvic fractures in children aged less than 12 years	NA	1. Average age – 7(range, 4.5-12) years 2. Sex ratio- M: F was 8:7 3. Mode of injury- - Pedestrian injuries 14 (93%) - Gunshot wounds 1 (7%) 4. Mortality – 3 (20%) 5. Vascular injury – 6 (40%) 6. Rectal injuries – 10 (66.7%) 7. Urinary tract injuries – 7 (46.6%) 8. Vaginal injuries – 5 (33.3%) 9. Sepsis – 11 (73.3%) (All survivors)
4.	Beslikas et al [12]., 2005, Greece	Case series	Total-1	Chronic osteomyelitis of the pelvis	NA	1. Age – 17 years 2. Sex – Male 3. Mortality- Nil 4. Associated with abdominal and urinary tract injury 5. Microbial flora isolated – *E. coli* 6. Antibiotics – Cefamandole
5.	Kataoka et al [8]., 2009, Japan	Retrospective observational study	Total – 11 Closed pelvic fractures – 6;	Fractures of the pelvis with peri-pelvic soft tissue infection	NA	1. Average age – 50.8 years 2. Sex ratio- M: F was 4:1 3. Mode of injury- - Motorcycle accidents – 2

			Open pelvic fractures -5			- Bicycle accident – 1 - Pedestrian injury – 1 - Vehicular accident – 1 4. Mortality – 3 (60%) 5. Major vessel injury (subjected to transcatheter angiographic embolization) – bilateral internal iliac arteries 3, right internal iliac artery 1, right deep femoral artery 1, left circumflex femoral artery 1, left lumbar artery 1 6. Rectal injuries – 3 (60%) 7. Urinary tract injuries – 2 (40%) 8. Uterine laceration – 1 (20%) 9. Microbial flora isolated- - *S. aureus* 4 - *E. coli* 4 - *K. pneumoniae* 1 - *E. faecium* 2 - *E. faecalis* 7 - *P. aeruginosa* 1 - *E. cloacae* 3 - *K. oxytoca* 1 - *S. marcescens* 2 - *Bacteroides sp.* 8 - *Pepto streptococcus sp.* 2 - *Bacillus sp.* 1 - *Candida sp.* 4 10. Broad spectrum antibiotics followed by culture specific therapy
6.	Rehman et al [13]., 2011, United States of America	Retrospective observational study	Total -84	Inclusion: Patients aged more than 12 years who presented to a Level 1 trauma centre following a gunshot pelvic fracture Exclusion: 1. Patients who died within 48 hours of injury 2. Lumbar spine fractures 3. Pelvic fractures secondary to other modes of injury 4. Shotgun injuries	NA	1. Average age – 27.2 (range, 13-71) years 2. Sex ratio- M: F was 80:4 3. Small bowel injuries – 30 4. Large bowel injuries – 31 (11 patients had both small and large bowel injuries) 5. Infection – 1 6. Broad spectrum antibiotics
7.	Govaert et al [11]., 2012, Australia	Case report	Total-1	NA	NA	1. Age – 32 years 2. Sex – Male 3. Mode of injury – Crush injury from heavy object 4. Mortality – Nil 5. Rectal injury present 6. Complete disruption of the penile suspensory ligament and membranous urethra present 7. Sepsis – Nil 8. Broad spectrum antibiotics
8.	Rizzi et al [7]., 2015, Italy	Case report	Total-1	NA	NA	1. Age – 31 years 2. Sex – Male 3. Mode of injury – Motorcycle accident 4. Mortality – Nil 5. Major vessel injury – Left Internal Iliac arterial branches 6. Perineal laceration present 7. Associated with lumbosacral dislocation

						8. Left scrotal laceration and testicular injury present 9. Sepsis – Yes 10. Microbial flora isolated - *P. aeruginosa* and *E. cloacae* 11. Culture specific antibiotics
9.	Medda et al [14]., 2020, United States of America	Case report	Total-1	NA	NA	1. Age – 18 years 2. Sex – Female 3. Mode of injury – Vehicular accident 4. Mortality – Nil 5. No neuro-vascular injury 6. Open Left obturator hip dislocation 7. Injury to the internal and external anal sphincter 8. Serosal tear of the caecum present 9. Vaginal wall laceration present 10. Sepsis – Yes 11. Microbial flora isolated - *P. aeruginosa, E. faecalis, E. coli, Acinetobacter*, coagulase *negative S. aureus* and *Bacteroides sp.* 12. Culture specific antibiotics- Piperacillin-Tazobactam
10.	Kusturova and Kusturov [15], 2026, Republic of Moldova	Case report	Total-1	NA	NA	1. Age – 29 years 2. Sex – Male 3. Mode of injury – Road traffic accident 4. Mortality – Nil 5. No neuro-vascular injury 6. Perineal wound present 7. Morel-Lavallee lesion present 8. Sepsis – No 9. Culture specific antibiotics

RESULTS:

(i) Demographics- A total of 10 studies, with 179 subjects were included in this analysis [3,4,7,8,10-15]. Half of the articles were retrospective reviews of trauma registries [3,4,8,10,13], while the remaining half were case reports [7,11,12,14,15]. The weighted mean age of the study population was 24.8 years, with 139 males and 40 female patients. The most common mode of injury noted was penetrating trauma secondary to gunshot wounds (GSWs). The next most frequently implicated cause was pedestrian injury followed by motorcycle accidents. One case each, due to fall from height and crush injury, was also reported [10,11].

(ii) Extent and severity of injuries- All OPFs result from high energy trauma. The weighted mean Injury Severity Score (ISS) calculated was 41.8 (three studies analyzed) [3,7,8]. Major vessel injury was reported in 23 out of 95 patients (24.2%) (nine articles analyzed) [3,4,7,8,10-12,14,15]. Only two studies estimated the extent of blood loss in terms of volume of resuscitation within the first 24 hours of admission [4,8]. This was calculated to 14,137 ml. A large proportion of OPFs were associated with underlying injuries to the large bowel as well as the urogenital system. Trauma to the small bowel was also reported in 32 subjects (17.9%). Most injuries involving the large intestine afflicted the anorectal canal (24 cases). Vaginal wall lacerations were reported in 18 patients, while injuries involving the vulva, testicular-scrotal system and the uterus were less frequently observed. The urinary tract was injured in 32 patients (17.9%). These included both intraperitoneal/extraperitoneal bladder ruptures as well as disruptions to the urethral lining. Other injuries reported included two cases of sciatic/peroneal nerve injury and one patient each of lumbosacral dislocation, open obturator dislocation and Morel-Lavallee lesion [4,7,14,15].

(iii) Mortality and sepsis- Sepsis was noted in 40 patients (22.3%) out of the entire study population. Overall mortality rate reported was 36 out of 95 subjects or 37.9% (nine studies analyzed) [3,4,7,8,10-12,14,15]. Of the latter, sepsis induced mortality stood at 47.5% (19/40 subjects). Five studies elaborated upon the nature of microbes isolated from the open pelvic wound. The authors observed that in addition to *S. aureus*, a number of gram-negative bacilli as well anaerobes were also frequently cultured. Notable isolates included *P. aeruginosa, E. faecalis, E. coli, E. cloacae, K. pneumoniae, Bacteroides sp.* etc. In a few instances, fungal element such as *Candida* have also been detected [7,8,10,12,14]. The source of this flora is not only the perineal secretions but also other potential contaminants such as faecal content, catheter tip etc. Most authors have recommended sending an intra-operative culture swab and initiating broad spectrum antimicrobial therapy, with switch to culture-based therapy in due course of time [4,7,8,10,11,13].

DISCUSSION:

Fractures of the pelvis account for approximately 3% of all musculoskeletal injuries, with reported mortality ranging from 10-16% [16-18]. OPFs are a rare subgroup of these injuries, with estimated incidence varying between 2-4% of all pelvic fractures [16,19]. In children, the frequency of OPFs reported is higher (12.9%) due to the inherent plasticity of the pelvis which, in turn, necessitates a higher degree of force to cause disruption of the pelvic ring [3]. A number of factors have been identified to correlate with the increased mortality seen in these injuries. These are: (i) age; (ii) ISS; (iii) pelvic instability; (iv) size and extent of contamination of the pelvic wound; (v) number of blood units transfused; (vi) degree of rectal injury and (vii) early faecal diversion [2,6,19]. It has been well established that initial exsanguinating haemorrhage and delayed sequelae such as sepsis are the two major contributing factors to the increased mortality seen in these patients. Hence, it is logical that efforts be made towards mitigation of these complications. Initial attempts at management involve aggressive resuscitation with intravenous crystalloids and blood products and control of bleeding through timely application of compression dressings or pelvic binding. A more definite strategy involves placing an external fixator/C-clamp to minimize bony instability followed by pelvic packing and angiographic embolization (AE), if haemorrhage is not controlled [1,2,4,9].

OPFs are more prone to wound related infection and sepsis than other injuries. A 25% infection rate amongst patients with OPFs with associated vaginal injuries has been reported by Li et al [20]. Contamination of the fractured site in these cases not only results from the external environment but also, in large part, from microbial growth in the genitourinary tract as well as the anal canal [1,2,8]. Kataoka et al [8]. demonstrated that skin and soft tissue necrosis in the peri pelvic area secondary to arterial cross-clamping or AE was a risk factor for infection of the underlying fracture hematoma and abscess formation. Another determinant of sepsis is the systemic impairment of host immunity following extensive haemorrhagic shock and repeated blood transfusions [8,21]. Once infection and sepsis set in in these critically injured patients, there is an increased risk of MODS. To mitigate this risk, a number of strategies have been devised. First, all open wounds must be thoroughly irrigated, preferably with a pulse lavage technique. This must be accompanied by repeated debridement of the necrotic tissue and removal of non-viable bony fragments. Often, periodic surgical revisions at 24-72 hourly interval are needed. In 1976, Raffa and Christensen demonstrated a reduction in mortality from 58 to 25% in OPFs where an early diverting colostomy or ileostomy was performed with distal rectal washout of residual faecal matter [22]. Faringer et al [23]. called this procedure as “selective faecal diversion”. Numerous authors have validated the usefulness of this technique, especially in zone 1 pelvi-perineal wounds [10,16]. Bladder decompression must also be carried out either through a suprapubic cystostomy or direct catheterization. The latter, however, must be attempted only if a retrograde cystourethrogram is negative for urethral injury [24]. The Princess Alexandra Hospital management protocol for OPFs includes external fixation of the pelvic fracture with vigorous soft tissue debridement and early, time bound faecal diversion to minimize contamination. The authors recommend using vacuum assisted closure (VAC) therapy to achieve early wound healing and adequate local tissue drainage [11]. Simultaneous restoration of cardiorespiratory status, appropriate nutritional support and early initiation of broad-spectrum antibiotics are of paramount importance [8,10].

According to literature, prompt antibiotic administration has been shown to significantly reduce infection rates when compared to patients with delayed antibiotic therapy [25]. In addition to timing, the coverage of empirical antimicrobial therapy needs to be broad spectrum given the presence of poly-microbial flora in the large bowel and genitourinary tract [26]. In a retrospective analysis of 48 OPFs, Birolini et al [10]. demonstrated numerus gram negative bacilli such as *K. pneumoniae* and *P. aeruginosa* among the bacterial isolates and recommended a combination therapy comprising of Crystalline Penicillin, Chloramphenicol and Gentamicin for initial management. Likewise, Beslikas et al [12]. identified a case of iliac wing osteomyelitis secondary to *E. coli* following an open pelvic injury, and used intravenous Cefamandole for treatment. Two instances of peri pelvic infection were noted by Medda et al [14]. in a case of open obturator hip dislocation, both of which revealed a mixed growth upon culture. Piperacillin-Tazobactam combination was used by the authors to successfully treat the infection. Another study by Kataoka et al [8]. on OPF induced sepsis, showed microflora in perineal secretions, bloodstream as well as catheter tip which encompassed gram-positive cocci, gram negative bacilli, anaerobes along with fungal elements like *Candida*. These were treated with broad spectrum antibiotics with conversion to culture specific drugs subsequently. An important factor compounding the selection of antibiotics is the presence of a vaginal laceration. While *Lactobacilli* predominate, infections due to other aerobic/anaerobic bacteria cannot be ruled out and there is limited research available [27]. In such scenarios, practice guidelines recommend adding a second-generation cephalosporin for systemic gram-positive coverage with additional antibiotics for gram negative and metronidazole for anaerobes on a case-to-case basis [28-30]. A few recent articles also advocate placing antibiotic impregnated polymethylmethacrylate (PMMA) beads or topical vancomycin powder within the pelvic wound as a way to enhance local antibiotic delivery [31,32].

RISK OF BIAS (ROB) OF INCLUDED STUDIES:

Author/year	NIH Quality Assessment tool for Observational Cohort Studies [33]														Study quality
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Rothenberger et al [4]., 1978	CD	Y	NA	Y	N	Y	Y	NA	NA	NA	Y	N	Y	NA	Fair
Birolini et al [10]., 1990	Y	CD	NA	Y	N	Y	Y	NA	NA	NA	Y	N	Y	NA	Fair
Mosheiff et al [3].,1999	CD	Y	NA	Y	N	Y	Y	NA	NA	NA	Y	N	Y	NA	Fair
Kataoka et al [8]., 2009	Y	Y	NA	Y	N	Y	Y	NA	NA	NA	Y	N	Y	NA	Fair
Rehman et al [13]., 2011	Y	Y	NA	Y	N	Y	Y	NA	NA	NA	Y	N	Y	NA	Fair

Table 1: ROB assessment of observational studies included in analysis.

Parameters # 3,8-10 and 14 were not applicable to any of the studies and hence were excluded

Scoring: Number of parameters checked “yes” out of 9. Good- ≥8; Fair- 6-7; Poor - ≤5

Y- Yes; N- No; NA- Not applicable; CD- Cannot be determined

Author/year	Murad Tool for evaluating methodological quality of case reports/series [34]								Study quality
	1	2	3	4	5	6	7	8	
Beslikas et al [12]., 2005	Y	CD	Y	NA	NA	NA	Y	Y	Good
Govaert et al [11]., 2012	Y	Y	Y	NA	NA	NA	Y	Y	Good
Rizzi et al [7]., 2015	Y	Y	Y	NA	NA	NA	Y	Y	Good
Medda et al [14]., 2020	Y	Y	Y	NA	NA	NA	Y	Y	Good
Kusturova and Kusturov [15], 2026	Y	Y	Y	NA	NA	NA	Y	Y	Good

Table 2: ROB assessment of case reports included in analysis.

Parameters # 4-6 were not applicable to any of the studies and hence were excluded

Scoring: Number of parameters checked “yes” out of 5. Good- ≥4; Fair- 3; Poor - ≤2

Y- Yes; NA- Not applicable; CD- Cannot be determined

RESPONSE/RECOMMENDATION:

	Open fractures of extremities	Open fractures of Pelvis
Microbial flora	Skin contaminants such as Coagulase negative *Staph*; *S. aureus*	Polymicrobial – Gram positive cocci, gram negative bacilli, anaerobes and fungal elements. For example- *S. aureus, E. coli, K. pneumoniae, E. faecium, E. faecalis, P. aeruginosa, E. cloacae, K. oxytoca, S. marcescens, Bacteroides, Candida sp. etc.*
Antibiotic regimen	Mostly first generation cephalosporins; In farmyard injuries and in cases with increased contamination, aminoglycosides and clindamycin/metronidazole recommended	Broad spectrum comprising of second generation cephalosporins, aminoglycosides for gram negative coverage and metronidazole for anaerobes initially. Switch to culture specific antibiotic therapy

LEVEL OF EVIDENCE:

Low

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