asymptomatic bacteriuria (AB) should not be routinely treated in these patients because of rising resistance patterns, in the case of symptomatic urinary tract infection (UTI) antibiotic treatment should be administered and antibiotic selection should be based on local and patient-based resistance patterns so that the spectrum can be as narrow as possible [5]. In this line, recent Clinical Guidelines for the Diagnosis and Treatment of UTI of the Spanish Society of Infectious Diseases state that screening for, and treatment of, AB prior to performing instrumental spinal surgery is recommended for patients with neurogenic bladders or urinary incontinence in order to reduce the risk of gram-negative SSIs [6].

It was reported that up to 61% of children with myelomeningocele have neurogenic bladders [7–9]. Hatlen et al. demonstrated that the presence of positive urinary cultures before elective spine surgery for children with myelomeningocele leads to an increased risk of perioperative spine infections [10]. Olsen et al. conducted a case-control study to determine independent risk factors for SSI following orthopaedic spinal operations [11]. Among the patient-level factors in the univariate analysis, any incontinence (bowel or bladder, or both and preoperative or postoperative) significantly increased the risk of SSIs.

Although gram-positive organisms (particularly *Staphylococcus aureus*) predominate as causative agents for SSIs in patients undergoing spine surgery, GNB accounted for a sizeable portion of SSIs, particularly among lower lumbar and sacral spine surgical procedures [2]. Patients with incontinence, neurogenic bladder or indwelling catheters are more prone to urinary tract colonization and infection and may therefore be at higher risk of SSIs by GNB [4]. Contamination by GNB should not occur during the operative procedure, as these microorganisms are not usually present among the patient's skin flora [12]. Previous studies have suggested that GNB contamination could be secondary to hematogenous seeding originating in the urinary tract or to local skin contamination in incontinent patients, especially those undergoing surgery at the lumbosacral level [12].

Nuñez-Pereira et al. hypothesized that detecting urinary tract colonization preoperatively and adjusting antibiotic prophylaxis according to urine culture results might lower the overall SSI rate by reducing the number of GNB infections [12]. They performed a retrospective cohort study comparing two consecutive groups of patients undergoing posterior spinal fusion and instrumentation at a single institution. Cohort A included 236 patients, operated on between January 2006 and March 2007, receiving standard preoperative antibiotic prophylaxis with cefazolin (clindamycin in allergic patients). Cohort B included 223 patients operated on between January and December 2009, receiving individualized antibiotic prophylaxis and treatment based on preoperative urine culture. The study demonstrated that preoperative urine culture and individualized antibiotic prophylaxis are associated with a significant decrease in SSI due to GNB in high-risk patients undergoing spinal surgery.

Measures aimed at preventing UTI in patients with neurogenic bladder such as closed catheter drainage in patients with an indwelling catheter and the use of clean intermittent catheterization could reduce the risk of perioperative spine infections [4]. Intravesical Botox, bacterial interference and sacral neuromodulation show significant promise for the prevention of UTIs in neurogenic bladder patients [5].

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1.3. PREVENTION: BONE GRAFT

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QUESTION 1: Does the use of allograft increase the risk of spinal infection?

RECOMMENDATION: The use of allograft seems to increase the risk for infection in pediatric and neuromuscular scoliosis, however there is no increased risk in the adult degenerative population.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 77%, Disagree 0%, Abstain: 23% (Super Majority, Strong Consensus)

RATIONALE

It has been postulated that infection risk from bone allograft may be caused by contamination or by the overwhelming of local host defenses [1,2]. Much of the data addressing this issue can be found in the pediatric literature. In a case-control study of 22 pediatric patients with infections after spine surgery, Croft et al. found that allograft use was strongly associated with surgical site infection (odds ratio (OR) = 10.7, $p < 0.0001$) [3]. Aleissa et al. showed similar results in 14 patients with SSI (risk rate (RR) 9.6, $p < 0.001$) [4]. Sponseller et al. were able to demonstrate a statistically significant increase in infection risk with the use of allograft versus autograft ($p = 0.010$) [5].

Several systematic reviews have also addressed this subject. Fei et al. performed a meta-analysis of risk factors for surgical site infection after spine surgery in 12 high-quality studies [6]. They found a relative risk for infection of 2.72% with the use of bone allograft, though there was a broad confidence interval and they failed to reach statistical significance at $p = 0.244$. Meng et al. [2] performed a systematic review of 13 studies of infection risk in pediatric spine surgery. The use of allograft carried an odds ratio of 8.498 with a high statistical significance at $p < 0.001$, though the authors cautioned about possible bias due to study heterogeneity. Glotzbecker et al. found grade C evidence of an association between allograft use and surgical site infection [7].

On the other hand, multiple studies have demonstrated that even in the pediatric literature, there is conflicting evidence. Knapp et al. studied patients with Adolescent Idiopathic Scoliosis (AIS) and found that allograft did not increase the risk for infection [8]. In a case-control study of pediatric patients undergoing spinal fusion, Shen et al. also found that there was no increased risk with allograft [9]. In the adult population, several large studies have failed to find an association between allograft use and infection. Mark et al. looked at over 1,400 patients who underwent spinal fusion, and there was no difference in infection rate when using allograft or autograft [10]. Similarly, Saeedinia et al. looked at almost 1,000 patients undergoing spinal surgery and failed to find an association between allograft and infection [11].

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QUESTION 2: Can allograft, synthetic bone substitute or autograft be used during revision spinal surgery in patients with prior spine infection?

RECOMMENDATION: Based on available data, it appears that allograft, autograft and synthetic cages may be used successfully along with posterior screw fixation and prolonged antibiotic therapy in the treatment of pyogenic spondylodiscitis. This data can probably be extrapolated to also confirm that allograft and autograft safe during revision spinal surgery with prior infection.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 93%, Disagree: 7%, Abstain: 0% (Super Majority, Strong Consensus)

RATIONALE

There are several small studies suggesting that bone allograft and autograft may be used successfully with posterior screw fixation and antibiotics to treat spine infections. Dobran et al. reviewed 18 patients who underwent posterior screw fixation along with allograft and autograft for pyogenic spondylodiscitis [1]. All patients had successful fusion and normalization of C-reactive protein at a mean follow-up of 30 months. Likewise, Chung et al. reported a study of 20 patients who underwent anterior fibular allograft and posterior screw fixation for spondylodiscitis [2]. All patients had significant improvement in pain and satisfaction scores, with at least 36 months of follow-up. Only two patients had superficial wound complications. In a third study, An et al. reviewed 15 patients who underwent mixed allograft and autograft with posterior screw fusion [3]. All but one showed significant improvement in neurological deficit, functional outcome and pain, with a mean follow-up of 27 months.

Synthetic materials have also been used in the successful treatment of pyogenic spondylodiscitis. Shiban et al. reported 52 patients treated with polyetheretherketone (PEEK) cages in combination with posterior pedicle screw fixation [4]. Patients received two weeks of intravenous and three months of oral antibiotic therapy. Infection was cured in all and 16 of the 28 with some neurologic deficit improved at 12 months of follow-up. Similar results were reported with PEEK cages and posterior fixation by Schomacher et al. (51 patients, 20 months of follow-up) and Brase et al. (nine patients,