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## INVITED REVIEW

# Epidemiology regarding penile prosthetic surgery

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With the onset of a metabolic syndrome epidemic and the increasing life expectancy, erectile dysfunction (ED) has become a more common condition. As incidence and prevalence increase, the medical field is focused on providing more appropriate therapies. It is common knowledge that ED is a chronic condition that is also associated with a myriad of other disorders. Conditions such as aging, diabetes mellitus, hypertension, obesity, prostatic hypertrophy, and prostate cancer, among others, have a direct implication on the onset and progression of ED. Characterization and recognition of risk factors may help clinicians recognize and properly treat patients suffering from ED. One of the most reliable treatments for ED is penile prosthetic surgery. Since the introduction of the penile prosthesis (PP) in the early seventies, this surgical procedure has improved the lives of thousands of men, with reliable and satisfactory results. The aim of this review article is to characterize the epidemiology of men undergoing penile prosthetic surgery, with a discussion about the most common conditions involved in the development of ED, and that ultimately drive patients into electing to undergo PP placement.

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## INTRODUCTION

Erectile dysfunction (ED) is the inability to obtain or maintain an erection suitable for sexual intercourse.<sup>1</sup> It is estimated that more than 50% of men between the ages of 40 and 70 years have suffered some degree of ED.<sup>2</sup> Moreover, it is well established that the severity and prevalence of ED will increase with age and with the appearance of other comorbidities.<sup>3</sup> It is also known that ED plays a major role in the adult male patient's well-being. There are many risk factors for ED, including age, obesity, smoking history, sleep apnea, hypertension, hypercholesterolemia, diabetes, cardiovascular disease, prostate cancer, and Peyronie's disease, amongst others.<sup>4</sup> It is important to point out that the incidence of some of these pathologies increased over the last few decades. For example, the rise in the prevalence of the metabolic syndrome, which encompasses conditions such as obesity, hypertension, dyslipidemia, and insulin resistance, is a well-known factor for the development of cardiovascular disease<sup>5</sup> and ED. Moreover, the increase in the number of patients presenting with the metabolic syndrome cluster is presently seen as an epidemic.<sup>6</sup> This fact, along with increased life expectancy in the overall population,<sup>7</sup> may explain the rise in the incidence and prevalence of ED.<sup>8</sup> To address this condition, multiple treatment modalities have been developed, from vacuum erection devices, oral and injectable medications that enhance erections, to penile prosthetic implants. Multiple algorithms have been created to treat patients with ED,<sup>9,10</sup> and the majority encourage physicians to start therapies with the least invasive approach. Even though most clinicians do not consider penile prosthetic surgery as a first-line therapeutic option, it is one of the most effective and satisfactory therapies available.<sup>11</sup> Given this fact, it is important to review the epidemiology with regard to penile prosthesis (PP) procedures.

## HISTORY OF PENILE PROSTHESIS

The first documented efforts to create an artificial penile erection came from the 16<sup>th</sup> century in France, when Ambroise Pare developed a wooden penis to aid patients with micturition.<sup>12</sup> Throughout the early part of the 20<sup>th</sup> century, several attempts to create artificial erections were made, ranging from inserting bones in the 1930s, to acrylic splints extracavernosally in the 1950s, to inserting polyethylene implants intracorporally in the 1960s.<sup>13</sup> However, it was not until the 1970s, when Scott *et al.*<sup>14</sup> and Small *et al.*<sup>15</sup> independently published the creation of a semirigid and an inflatable PP, respectively. Since then, penile implants have evolved with the advent of new technologies, especially in the field of implant materials and design. Nowadays, with refinements in surgical technique, penile implantation has improved to become a safe, highly reproducible, and less-invasive procedure.<sup>16</sup>

## EPIDEMIOLOGY AND HISTORY LEADING TO PENILE PROSTHESIS

It is important to recognize the pathologies that ultimately lead to prosthetic surgery. Although PP implantation is not usually considered as a primary therapy for the treatment of ED, its success and satisfaction rates make it an attractive option. Since the introduction of the phosphodiesterase type 5 (PDE5) inhibitors in the 1990s, these medications became the first line of therapy for this condition;<sup>17</sup> however, roughly one-third of patients will fail to respond satisfactorily to oral or medical therapy.<sup>18</sup> In spite of this, Lee *et al.*<sup>19</sup> showed that only 3% of patients diagnosed with ED between 2001 and 2010 underwent PP surgery. In cases of severe ED, as in nonnerve-sparing prostatic cancer surgery, severe vasculogenic disease, priapism, and Peyronie's disease, the penile implant can also be recommended as the primary therapy, given that medical therapy is likely to yield poor results.

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The aim of this systematic review is to determine the epidemiology and history of ED treatment that ultimately results in PP placement. The PubMed database was searched from 1990 to 2018 using keywords (*i.e.*, “penile implant,” “penile prosthesis”) that identify retrospective series describing PP placement for the treatment of ED. Data were extracted from articles’ tables and methods section. Risk of bias could not be assessed due to variability in design of the selected articles. Articles were reviewed and relevant articles were selected according to the following inclusion criteria: (1) subject number more than 40 patients, (2) studies describing at least four primary etiologies of ED, and (3) series with PP models not undergoing clinical trials. A total of 104 articles were identified and reviewed, of which 27<sup>20–46</sup> met the inclusion criteria (**Table 1**). All studies were retrospective observational cohorts in nature. Data were analyzed in two distinct manners. First, reported means and percentages throughout the selected articles were combined and averaged percentages were obtained for each selected parameter. This was done by adding the reported percentages, by etiology, and by dividing them by the total number of articles in which they were reported. Then, all patients and comorbidities across the series were pooled, and percentages were calculated from the common pool.

### Age

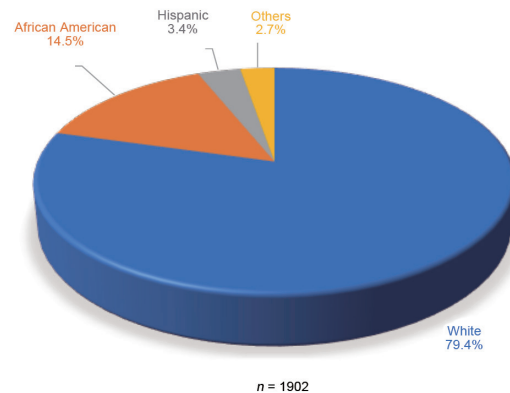
Throughout a total of 27 PP series, the mean age for implant placement was 59.12 years. The fact that ED incidence, prevalence, and severity increase with age has been vastly demonstrated across all publications.<sup>3,47,48</sup> The Massachusetts Male Aging Study showed that the risk of ED is about 26 cases per 1000 person-years.<sup>47</sup> Along with an increased incidence of new cases, the relative risk of worsening sexual function also increases with age.<sup>3</sup> These facts are associated with an increased prevalence of other comorbidities in the elderly. Many conditions that predispose to ED are also considered age related. Disorders such as cardiovascular disease, metabolic abnormalities, endocrinological disorders, and neurological diseases are also well known to increase with age.<sup>49</sup>

### Race

Most studies show that ED occurrence varies with race.<sup>3,4,47,48,50</sup> The prevalence of moderate-to-severe ED is approximately 22% for all races (21.9% Whites, 24.4% African-Americans, and 19.9% Hispanics).<sup>50</sup> Differences in lifestyle, diabetes, hypertension, education, and socioeconomic and relationship status are factors that affect the probability of severe ED.<sup>50</sup> One study shows that Hispanic men are twice as likely to complain about ED when compared to Caucasian patients, and African-American rates of outpatient ED-related visits are 3–5-fold higher than those of Hispanics or Caucasians.<sup>51</sup> Studies also show that Caucasian patients and those with private insurance were associated with a higher probability to be PP recipients.<sup>52</sup> Across the series analyzed in this review, five studies<sup>25,29,39,42,44</sup> reported race as one of the demographic variables. Of a total of 1902 patients who underwent PP surgery (**Figure 1**), 79.4% were Whites ( $n = 1511$ ), 14.5% were African-Americans ( $n = 276$ ), 3.4% were Hispanics ( $n = 65$ ), and 2.7% were other races ( $n = 51$ ).

### Comorbidities

ED may be caused by multiple underlying conditions (**Figure 2**). Across the analyzed series, the lack of standardization in reporting medical conditions and the fact that multiple diseases may be affecting a single patient make the identification of a primary cause of ED difficult. The most commonly described comorbidities across these series were diabetes mellitus and vascular diseases.



**Figure 1:** Penile prosthesis by race.

### Diabetes mellitus

Diabetes is one of the most common comorbidities affecting patients who undergo PP. The pathophysiology of diabetes-induced ED is multifactorial. Mechanisms include an excess of free radicals, damage to the nitric oxide (NO)-producing endothelium, neuropathic and myogenic damage, and even impaired protein function.<sup>53</sup> Selvin *et al.*<sup>4</sup> showed that the prevalence of ED in diabetic patients is roughly 50%. Moreover, of the 27 selected articles in this review, 26<sup>20–32,34–46</sup> described patients with diabetes mellitus who underwent PP placement. The mean incidence of diabetes was 26.3% (range: 12.7%–45.3%).

### Vascular causes

Erectile dysfunction and vascular disease are well known to share a common pathophysiology, through endothelial dysfunction.<sup>54</sup> It has also been established that ED is closely associated with cardiovascular disease.<sup>55</sup> In the medical literature, vascular conditions affecting erectile function encompass a variety of diseases, from cardiovascular disease, hypertension, and cavernosal arterial insufficiency to intrinsic corporovenous occlusive insufficiency. There is no standardization in reporting vascular conditions throughout the ED literature. Nevertheless, vascular etiologies are the most common pathologies identified in patients undergoing PP surgery. In modern series, vascular disease represents the main cause of ED in 35.8% of patients (mean: 11.0%–61.3%).

### Surgical causes

Pelvic surgeries, especially radical prostatectomy, have been historically considered as one of the most common causes of ED.<sup>56</sup> The proposed mechanism has been direct vascular trauma and neurologic damage to the plexus that provides innervation to the corpora.<sup>56</sup> Improvements in surgical technique, with the preservation of neurovascular bundles to the penis, have improved the outcomes in terms of erectile function.<sup>57</sup> Furthermore, the use of robotic techniques claims a modest improvement in outcomes with regard to ED.<sup>58</sup> Modern series estimates that approximately 33.8% of patients undergoing PP placement also underwent some forms of pelvic surgery (23.6% radical prostatectomy and 10.2% other pelvic surgeries).

### Radiotherapy

Radiotherapy (RTX) to the pelvis, most commonly for prostate cancer, has also been described as a source of ED in many studies. The pathophysiology involves radiation damage to the neurovascular bundles, pudendal and accessory pudendal arteries, as well as direct damage to the cavernosal smooth muscle and penile bulb.<sup>59</sup> Tal *et al.*<sup>60</sup>

Table 1: Penile prosthesis series

| Study                                  | Patients<br>(n) | Age<br>(year) | Diabetes,<br>% (n) | Vascular,<br>% (n) | RP, % (n)    | Pelvic<br>surgery, % (n) | RTX,<br>% (n) | Peyronie's,<br>% (n) | Priapism,<br>% (n) | Trauma,<br>% (n) | Neuro,<br>% (n) | Others,<br>% (n) | Revisions,<br>% (n) |
|--|-----------------|---------------|--------------------|--------------------|--------------|--------------------------|---------------|----------------------|--------------------|------------------|-----------------|------------------|---------------------|
| Gofrit <i>et al.</i> <sup>20</sup>     | 57              | 55            | 24.5 (14)          | 40.3 (23)          | —            | 26.3 (15)                | —             | —                    | —                  | —                | —               | —                | —                   |
| Menard <i>et al.</i> <sup>21</sup>     | 254             | 58.6          | 22.8 (58)          | 35.3 (90)          | 16.5 (42)    | 1.1 (3)                  | —             | 13.2 (34)            | 2.2 (5)            | 0.4 (1)          | 3.3 (8)         | 5.1 (13)         | —                   |
| Minervini <i>et al.</i> <sup>22</sup>  | 447             | 52            | 27.3 (122)         | 25.7 (115)         | —            | 10.3 (46)                | —             | 11.6 (52)            | 6.7 (30)           | 6.3 (28)         | 7.2 (32)        | 4.9 (22)         | (43)                |
| Cumming and Pryor <sup>23</sup>        | 130             | —             | 25 (33)            | 14 (19)            | —            | 8.5 (11)                 | —             | 18 (23)              | 8 (10)             | 8 (10)           | 7 (9)           | 11.5 (15)        | —                   |
| Garber <sup>24</sup>                   | 150             | 60            | 40 (60)            | 61.3 (90)          | —            | 4.6 (7)                  | —             | 3.3 (5)              | —                  | —                | 2 (3)           | 0.6 (1)          | (9)                 |
| Lotan <i>et al.</i> <sup>25</sup>      | 151             | 58            | 29 (44)            | 22 (33)            | —            | —                        | —             | —                    | —                  | —                | —               | —                | —                   |
| Ji <i>et al.</i> <sup>26</sup>         | 74              | 57.0          | 21.6 (16)          | 20.3 (15)          | —            | —                        | —             | 8.1 (6)              | —                  | 13.5 (10)        | 12.2 (9)        | 24.3 (18)        | —                   |
| Souillac <i>et al.</i> <sup>27</sup>   | 96              | 54.4          | 22.9 (22)          | 21.9 (21)          | 6.25 (6)     | 10.4 (10)                | —             | 8.3 (8)              | 13.5 (13)          | —                | 5.2 (5)         | 17.74 (17)       | (22)                |
| Montorsi <i>et al.</i> <sup>28</sup>   | 200             | 55            | —                  | 44 (88)            | —            | —                        | —             | 28 (56)              | 1 (2)              | 0.5 (1)          | 16.5 (33)       | 3 (6)            | 7 (14)              |
| Carson <i>et al.</i> <sup>29</sup>     | 372             | 57.6          | 12.9 (48)          | 27.7 (103)         | 9.4 (35)     | 2.2 (8)                  | 1.3 (5)       | 16.9 (63)            | —                  | 1.1 (4)          | 2.2 (8)         | 5.9 (22)         | —                   |
| Ohl <i>et al.</i> <sup>30</sup>        | 113             | 61.0          | 31.9 (36)          | 34.5 (39)          | 26.5 (30)    | 8.8 (10)                 | —             | 23.9 (27)            | —                  | 4.4 (5)          | 4.4 (5)         | 12.49 (15)       | —                   |
| Lux <i>et al.</i> <sup>31</sup>        | 146             | 58.7          | 13 (19)            | 56 (82)            | 16 (24)      | 3 (4)                    | —             | 11 (16)              | —                  | —                | 1 (1)           | —                | —                   |
| Goldstein <i>et al.</i> <sup>32</sup>  | 434             | 61            | 13 (56)            | 56 (242)           | —            | —                        | —             | 6 (26)               | —                  | —                | 6 (26)          | 19 (84)          | 18 (76)             |
| Levine <i>et al.</i> <sup>33</sup>     | 131             | 56.8          | —                  | 62 (81)            | 17 (22)      | 2 (3)                    | —             | 15 (20)              | —                  | —                | —               | 4 (5)            | —                   |
| Vitarrelli <i>et al.</i> <sup>34</sup> | 80              | 56            | 33.8 (25)          | 20 (24)            | —            | 43.2 (32)                | —             | 16.2 (12)            | 1.4 (1)            | —                | 5.4 (4)         | —                | (6)                 |
| Kim <i>et al.</i> <sup>35</sup>        | 397             | 63.1          | 28.5 (113)         | 21.2 (84)          | —            | 3 (12)                   | —             | 7.8 (31)             | —                  | 8 (32)           | 17.1 (68)       | 13.1 (52)        | —                   |
| Natali <i>et al.</i> <sup>36</sup>     | 200             | 58.9          | 41 (82)            | 11 (22)            | 22.5 (45)    | 15.5 (31)                | —             | 10 (20)              | —                  | —                | —               | —                | —                   |
| Chiang <i>et al.</i> <sup>37</sup>     | 331             | —             | 12.7 (42)          | 73.5 (243)         | —            | 0.6 (2)                  | —             | 6.6 (22)             | 0.6 (2)            | —                | 2.7 (5)         | 1.8 (6)          | 1.5 (9)             |
| Carson <i>et al.</i> <sup>38</sup>     | 39 005          | 62.15         | 21.6 (6695)        | 54.3 (16 463)      | 25.55 (8411) | 4.5 (1130)               | —             | 11.15 (3330)         | —                  | —                | 0.8 (239)       | 4.65 (1615)      | —                   |
| Henry <i>et al.</i> <sup>39</sup>      | 114             | 63            | 38.6 (44)          | —                  | 35.05 (40)   | —                        | —             | 14 (16)              | —                  | —                | —               | 12.2 (14)        | —                   |
| Ralla <i>et al.</i> <sup>40</sup>      | 51              | 61            | 21.6 (11)          | —                  | —            | 27.5 (14)                | 3.9 (2)       | 3.9 (2)              | 2 (1)              | —                | 5.9 (3)         | 43.1 (22)        | —                   |
| Otero <i>et al.</i> <sup>41</sup>      | 248             | 58.45         | 28.5 (67)          | 19.5 (45)          | 27 (68)      | —                        | 8 (16)        | —                    | —                  | —                | —               | 23.5 (61)        | —                   |
| Bennet <i>et al.</i> <sup>42</sup>     | 1135            | 63.39         | 20.3 (230)         | 18 (204)           | 27.4 (311)   | —                        | —             | 10.3 (117)           | 1.4 (16)           | —                | —               | 22.6 (257)       | —                   |
| Dhabuwalla <i>et al.</i> <sup>43</sup> | 339             | 61.25         | 27.9 (92)          | 56 (183)           | 40.3 (146)   | —                        | —             | 9.66 (32)            | 2.2 (7)            | —                | 2.83 (9)        | —                | 27.6 (90)           |
| Paranhos <i>et al.</i> <sup>44</sup>   | 139             | 62.68         | 45.3 (63)          | 21.6 (30)          | 25.9 (36)    | —                        | —             | 6.5 (9)              | —                  | —                | 3.6 (5)         | —                | 8.6 (12)            |
| Pryor <i>et al.</i> <sup>45</sup>      | 40              | 66.2          | 30 (12)            | 32.5 (13)          | 50 (20)      | 10 (4)                   | —             | —                    | —                  | 5 (2)            | —               | 12.5 (5)         | —                   |
| Liberman <i>et al.</i> <sup>46</sup>   | 90              | 56.8          | 25.5 (23)          | 46.6 (42)          | 8.8 (8)      | 2.2 (2)                  | —             | —                    | —                  | —                | 14.4 (13)       | 2.2 (2)          | —                   |

RP: radical prostatectomy; RTX: radiotherapy to the pelvis; Neuro: neurological conditions; —: no patients with this condition reported

analyzed over 52 000 patients, using the SEER database, who underwent radiation therapy for prostate cancer, and determined that the penile implant utilization rate was 0.3%. Three<sup>29,40,41</sup> of the 27 studies utilized in this review included patients who underwent pelvic radiation therapy in their cohort. On average, 4.4% (range: 1.3%–8%) of patients undergoing PP surgery received radiation.

### Peyronie's disease

Peyronie's disease is commonly described as an inflammatory response at the level of the tunica albuginea, which is followed by plaque formation that may cause penile curvature, pain, and ultimately erectile dysfunction.<sup>61</sup> The pathophysiology of ED has been proposed to be associated with corporovenous occlusive dysfunction.<sup>62</sup> Moreover, some proposed algorithms recommend the use of PP for the treatment of concomitant Peyronie's disease and medium-to-severe ED.<sup>63</sup> The mean incidence of Peyronie's disease in PP recipients in this review was 11.93% (range: 3.9%–28%), being reported in 22<sup>21–24,26–40,42–44</sup> of the 27 series.

### Priapism

Described as an unwanted prolonged erection lasting for more than 4 h, priapism is a recognized cause of ED. The severity of dysfunction will vary depending on the duration of the event. For example, approximately 90% of patients with priapism lasting more than 24 h will develop severe ED.<sup>64</sup> The resulting corporal fibrosis and the onset of corporovenous occlusive disease are the most common causes of priapism-induced ED.<sup>65</sup> Some authors suggest that immediate insertion of PP after prolonged, or refractory, ischemic priapism episode is the best management in these patients who will inevitably develop severe erectile dysfunction.<sup>66</sup> In our review, 10<sup>21–23,27,28,34,37,40,42,43</sup> out of the 27 cohorts described PP placement in patients who had suffered from priapism. However, the timing of prosthetic surgery and the severity of the priapism were not described. On average, 3.9% (range: 0.6%–13.5%) of patients receiving PP presented with priapism or its sequelae.

### Trauma

Traumatic causes of ED are reported differently throughout literature. In our review, we define trauma as direct injury to the penis or pelvic bones, causing ED severe enough to require PP surgery. Nine<sup>21–23,26,28–30,35,45</sup> of the 27 articles in this review describe patients who suffered trauma and underwent prosthesis implantation with a mean overall percentage of 5.4% (range: 0.4%–13.5%). The pathophysiology varies from neurologic and vascular injury to the development of penile fibrosis and venous occlusive dysfunction.<sup>67</sup>

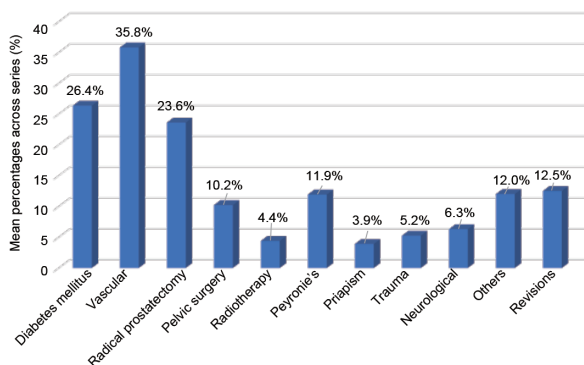


Figure 2: Cause of erectile dysfunction.

### Neurological conditions

ED in neurogenic patients is related to the loss of central nervous system control over the sacral centers of erection, precluding patients to control the timing of natural erections and making spontaneous intercourse almost impossible.<sup>68</sup> In spinal cord injury patients, PP has become a very reliable and safe method to treat ED.<sup>69</sup> The average incidence of neurogenic ED in patients undergoing PP is 5.8% (range: 0.8%–17%), reported in 19<sup>21–24,26–32,34,35,37,38,40,43,44,46</sup> of the 27 cohorts in this review.

### Other causes

Throughout the reviewed series, many other causes of ED that required PP placement have been described. Etiologies vary from PP placement for neophalluses, psychogenic ED, endocrine disorders, idiopathic ED, liver failure, posttransurethral procedures, to unknown causes. Up to 12% (range: 1.8%–43.1%) of patients who required prosthetic surgery in the reviewed literature will have uncommon causes that cannot be homogeneously catalogued.

### Revision surgery

It is important to mention that revision surgery for PP failure was described in one-third (9/27) of the reviewed series. On average, 12.5% (range: 1.5%–27.6%) of patients in these series underwent revision surgery due to PP malfunction. Wilson *et al.*<sup>70</sup> established that the revision-free survival at 10 years is 68.5% for the first-time inflatable PP placed by a single-surgical group. In a more recent analysis, Onyeji *et al.*<sup>71</sup> showed an overall IPP revision rate to be 6.9%, in a cohort of 14 969 patients with a median follow-up of 7.9 years. Therefore, it is not uncommon for modern descriptive series to mention patients undergoing surgery for either PP malfunction or explantation for infection.

### ANALYSIS OF COMBINED PATIENTS' CHARACTERISTICS

Meticulous study selection allows homogenization among the series described in this review and therefore permits the construction of a common patient pool to determine PP epidemiology more accurately. Differences in center specialization throughout the literature may skew the percentages of some common pathology reported in the published series. For example, implanters near cancer centers may treat more cancer survivors, who may have undergone radiotherapy or pelvic surgery, compared to implanters working at big trauma centers.

We analyzed a total of 41 887 first-time PP recipients reported in the 27 series and that constitutes our pooled population. We found some similarities and differences when we compared the results from the patient's pool to the averaged series (Figure 3). For example, patients with vascular disease amount to 39.1% of the pooled population versus 35.8% of the averaged results. Similar changes were

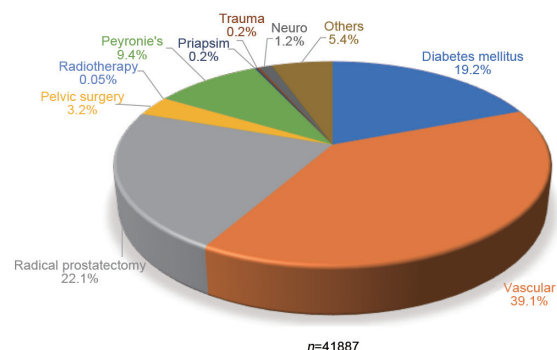


Figure 3: Pooled patients' characteristics.



observed when analyzing diabetic patients who received PP, in which the pooled population shows a 19.1% incidence versus a 26.3% in the averaged results. More similarities in the results are documented in radical prostatectomy patients (22.1% combined vs 23.6% in the averaged series) and Peyronie's disease patients (9.4% combined vs 11.9% in averaged series).

## STRENGTHS AND LIMITATIONS

One of the weaknesses of this review is the quality of the analyzed series. Not all series encompass the full spectrum of reported pathologies, and some do not have standard definitions reporting vascular disease or the type of pelvic surgeries performed on PP recipients. Moreover, as previously mentioned, the percentages of patients reported will reflect the series' main population and will vary according to the characteristics of each different practice. Furthermore, the results of the pooled population will be mainly influenced by the largest patient series in this review. Carson *et al.*<sup>29</sup> reported 39 005 patients, utilizing data from multiple centers, and including seven different etiologies, as well as age and race, which makes it one of the most reliable series utilized in this review in terms of patient characteristics. The main strength of this review is the use of modern series, which differ from older series in the degree of complexity regarding patient characteristic details and a better understanding of common etiologies of severe ED.

## CONCLUSION

The primary ED etiologies, which required PP surgery for severe ED, across modern series, are vascular disease, diabetes, and radical prostatectomy. Percentages regarding the main causes of ED requiring prosthetic surgery vary slightly when comparing averages versus a pooled population analysis. However, least common etiologies, such as trauma and radiation therapy, will vary considerably depending on the practice. Across series, the average age of PP recipients was 59.12 years and Caucasian patients constitute 79% of the reported population. Knowledge of etiologies and average age regarding PP procedures will aid primary physicians and urologists at the time of counseling patients who may be considering surgery as a treatment option for ED.

## AUTHOR CONTRIBUTIONS

JASB contributed to the drafting, acquisition, and analysis of data. JCH and RW revised, read, and approved the final manuscript.

## COMPETING INTERESTS

All authors declare no competing interests.

## REFERENCES

- 1 NIH Consensus Conference. Impotence: NIH consensus development panel on impotence. *JAMA* 1993; 270: 83–90.
- 2 Feldman HA, Goldstein I, Hatzichristou DG, Krane RJ, McKinlay JB. Impotence and its medical and psychosocial correlates: results of the Massachusetts male aging study. *J Urol* 1994; 151: 54–61.
- 3 Bacon CG, Mittleman MA, Kawachi I, Giovannucci E, Glasser DB, *et al.* Sexual function in men older than 50 years of age: results from the health professionals follow-up study. *Ann Intern Med* 2003; 139: 161–8.
- 4 Selvin E, Burnett AL, Platz EA. Prevalence and risk factors for erectile dysfunction in the US. *Am J Med* 2007; 120: 151–7.
- 5 Eckel RH, Alberti KG, Grundy SM, Zimmet PZ. The metabolic syndrome. *Lancet* 2010; 375: 181–3.
- 6 Haffner S, Taegtmeier H. Epidemic obesity and the metabolic syndrome. *Circulation* 2003; 108: 1541–5.
- 7 Mathers CD, Stevens GA, Boerma T, White RA, Tobias MI. Causes of international increases in older age life expectancy. *Lancet* 2015; 385: 540–8.
- 8 Ayta IA, McKinlay JB, Krane RJ. The likely worldwide increase in erectile dysfunction between 1995 and 2025 and some possible policy consequences. *BJU Int* 1999; 84: 50–6.
- 9 Wespes E, Amar E, Hatzichristou D, Hatzimouratidis K, Montorsi F, *et al.* EAU Guidelines on erectile dysfunction: an update. *Eur Urol* 2006; 49: 806–15.

- 10 Hatzimouratidis K, Hatzichristou DG. Looking to the future for erectile dysfunction therapies. *Drugs* 2008; 68: 231–50.
- 11 Mulhall JP, Ahmed A, Branch J, Parker M. Serial assessment of efficacy and satisfaction profiles following penile prosthesis surgery. *J Urol* 2003; 169: 1429–33.
- 12 Shah J. Erectile dysfunction through the ages. *BJU Int* 2002; 90: 433–41.
- 13 Henry GD. Historical review of penile prosthesis design and surgical techniques: part 1 of a three-part review series on penile prosthetic surgery. *J Sex Med* 2009; 6: 675–81.
- 14 Scott FB, Bradley WE, Timm GW. Management of erectile impotence use of implantable inflatable prosthesis. *Urology* 1973; 2: 80–2.
- 15 Small MP, Carrion HM, Gordon JA. Small-Carrion penile prosthesis: new implant for management of impotence. *Urology* 1975; 5: 479–86.
- 16 Le B, Burnett AL. Evolution of penile prosthetic devices. *Korean J Urol* 2015; 56: 179–86.
- 17 Hatzimouratidis K, Amar E, Eardley I, Giuliano F, Hatzichristou D, *et al.* Guidelines on male sexual dysfunction: erectile dysfunction and premature ejaculation. *Eur Urol* 2010; 57: 804–14.
- 18 McMahon CN, Smith CJ, Shabsigh R. Treating erectile dysfunction when PDE5 inhibitors fail. *BMJ* 2006; 332: 589–92.
- 19 Lee DJ, Najari BB, Davison WL, Al Awamih BA, Zhao F, *et al.* Trends in the utilization of penile prostheses in the treatment of erectile dysfunction in the United States. *J Sex Med* 2015; 12: 1638–45.
- 20 Gofrit ON, Shenfeld OZ, Katz R, Shapiro A, Landau EH, *et al.* Penile prosthesis for erectile dysfunction—long-term follow-up. *Harefuah* 2000; 139: 183–6.
- 21 Menard J, Tremereux JC, Faix A, Staerman F. Penile prostheses multicentre practice evaluation, results after 282 procedures. *Prog Urol* 2007; 17: 229–34.
- 22 Minervini A, Ralph DJ, Pryor JP. Outcome of penile prosthesis implantation for treating erectile dysfunction: experience with 504 procedures. *BJU Int* 2006; 97: 129–33.
- 23 Cumming J, Pryor JP. Treatment of organic impotence. *Br J Urol* 1991; 67: 640–3.
- 24 Garber BB. Inflatable penile prosthesis: results of 150 cases. *Br J Urol* 1996; 78: 933–5.
- 25 Lotan Y, Roehrborn CG, McConnell JD, Hendin BN. Factors influencing the outcomes of penile prosthesis surgery at a teaching institution. *Urology* 2003; 62: 918–21.
- 26 Ji YS, Ko YH, Song PH, Moon KH. Long-term survival and patient satisfaction with inflatable penile prosthesis for the treatment of erectile dysfunction. *Korean J Urol* 2015; 56: 461–5.
- 27 Souillac I, Pignot G, Galiano M, Hastert V, Sibaud O, *et al.* Inflatable penile prostheses: Results, complications and prognostic factors. *Prog Urol* 2009; 19: 563–71. [Article in French].
- 28 Montorsi F, Rigatti P, Carmignani G, Corbu C, Campo B, *et al.* AMS three-piece inflatable implants for erectile dysfunction: a long-term multi-institutional study in 200 consecutive patients. *Eur Urol* 2000; 37: 50–5.
- 29 Carson CC, Mulcahy JJ, Govier FE; AMS 700CX Study Group. Efficacy, safety and patient satisfaction outcomes of the AMS 700CX inflatable penile prosthesis: results of a long-term multicenter study. *J Urol* 2000; 164: 376–80.
- 30 Ohl DA, Brock G, Ralph D, Bogache W, Jones L, *et al.* Prospective evaluation of patient satisfaction, and surgeon and patient trainer assessment of the coloplast titan one touch release three-piece inflatable penile prosthesis. *J Sex Med* 2012; 9: 2467–74.
- 31 Lux M, Reyes-Vallejo L, Morgentaler A, Levine LA. Outcomes and satisfaction rates for the redesigned 2-piece penile prosthesis. *J Urol* 2007; 177: 262–6.
- 32 Goldstein I, Newman L, Baum N, Brooks M, Chaikin L, *et al.* Safety and efficacy outcome of mentor alpha-1 inflatable penile prosthesis implantation for impotence treatment. *J Urol* 1997; 157: 833–9.
- 33 Levine LA, Estrada CR, Morgentaler A. Mechanical reliability and safety of, and patient satisfaction with the ambicor inflatable penile prosthesis: results of a 2 center study. *J Urol* 2001; 166: 932–7.
- 34 Vitarelli A, Divenuto L, Fortunato F, Falco A, Pagliarulo V, *et al.* Long term patient satisfaction and quality of life with AMS700CX inflatable penile prosthesis. *Arch Ital Urol Androl* 2013; 85: 133–7.
- 35 Kim DS, Yang KM, Chung HJ, Choi HM, Choi YD, *et al.* AMS 700CX/CXM inflatable penile prosthesis has high mechanical reliability at long-term follow-up. *J Sex Med* 2010; 7: 2602–7.
- 36 Natali A, Olinas R, Fisch M. Penile implantation in Europe: successes and complications with 253 implants in Italy and Germany. *J Sex Med* 2008; 5: 1503–12.
- 37 Chiang HS, Wu CC, Wen TC. 10 years of experience with penile prosthesis implantation in Taiwanese patients. *J Urol* 2000; 163: 476–80.
- 38 Carson CC, Mulcahy JJ, Harsch MR. Long-term infection outcomes after original antibiotic impregnated inflatable penile prosthesis implants: up to 7.7 years of followup. *J Urol* 2011; 185: 614–8.
- 39 Henry GD, Kansal NS, Callaway M, Grigsby T, Henderson J, *et al.* Centers of excellence concept and penile prostheses: an outcome analysis. *J Urol* 2009; 181: 1264–8.
- 40 Ralla B, Goranova I, Börnstein N, Friedersdorff F, Maxeiner A, *et al.* Complications, functional and quality of life outcomes following primary and secondary implantation of penile prosthesis at a tertiary referral center. *Int J Impot Res* 2018; 30: 49–53.
- 41 Otero JR, Cruz CR, Gómez BG, Geli JS, Polo JM, *et al.* Comparison of the patient

- and partner satisfaction with 700CX and Titan penile prostheses. *Asian J Androl* 2017; 19: 321–5.
- 42 Bennett N, Henry G, Karpman E, Brant W, Jones L, *et al*. Inflatable penile prosthesis implant length with baseline characteristic correlations: preliminary analysis of the PROPPER study. *Trans Androl Urol* 2017; 6: 1167–74.
- 43 Dhabuwala C, Sheth S, Zamzow B. Infection rates of rifampin/gentamicin-coated Titan Coloplast penile implants. Comparison with Inhibizone-impregnated AMS penile implants. *J Sex Med* 2011; 8: 315–20.
- 44 Paranhos M, Andrade E, Antunes AA, Barbieri AL, Claro JA, *et al*. Penile prosthesis implantation in an academic institution in Latin America. *Int Braz J Urol* 2010; 36: 591–601.
- 45 Pryor MB, Carrion R, Wang R, Henry G. Patient satisfaction and penile morphology changes with postoperative penile rehabilitation 2 years after coloplast Titan prosthesis. *Asian J Androl* 2016; 18: 754–8.
- 46 Liberman SN, Gomella LG, Hirsch IH. Experience with the ultrex and ultrex Plus inflatable penile prosthesis: new implantation techniques and surgical outcome. *Int J Impot Res* 1998; 10: 175–9.
- 47 Johannes CB, Araujo AB, Feldman HA, Derby CA, Kleinman KP, *et al*. Incidence of erectile dysfunction in men 40 to 69 years old: longitudinal results from the Massachusetts male aging study. *J Urol* 2000; 163: 460–3.
- 48 Laumann EO, Paik A, Rosen RC. Sexual dysfunction in the United States: prevalence and predictors. *JAMA* 1999; 281: 537–44.
- 49 Corona G, Mannucci E, Mansani R, Petrone L, Bartolini M, *et al*. Aging and pathogenesis of erectile dysfunction. *Int J Impot Res* 2004; 16: 395–402.
- 50 Laumann EO, West S, Glasser D, Carson C, Rosen R, *et al*. Prevalence and correlates of erectile dysfunction by race and ethnicity among men aged 40 or older in the United States: from the male attitudes regarding sexual health survey. *J Sex Med* 2007; 4: 57–65.
- 51 Wessells H, Joyce GF, Wise M, Wilt TJ. Erectile dysfunction. *J Urol* 2007; 177: 1675–81.
- 52 Mirheydar HS, Palazzi KL, Parsons JK, Chang D, Hsieh TC. Hospital-based trends in penile prosthetic surgery. *J Sex Med* 2015; 12: 1092–8.
- 53 Thorve VS, Kshirsagar AD, Vyawahare NS, Joshi VS, Ingale KG, *et al*. Diabetes-induced erectile dysfunction: epidemiology, pathophysiology and management. *J Diabetes Complications* 2011; 25: 129–36.
- 54 Gandaglia G, Briganti A, Jackson G, Kloner RA, Montorsi F, *et al*. A systematic review of the association between erectile dysfunction and cardiovascular disease. *Eur Urol* 2014; 65: 968–78.
- 55 Schouten BW, Bohnen AM, Bosch JL, Bernsen RM, Deckers JW, *et al*. Erectile dysfunction prospectively associated with cardiovascular disease in the Dutch general population: results from the Krimpen study. *Int J Impot Res* 2008; 20: 92–9.
- 56 Eardley I. Pathophysiology of erectile dysfunction. *British J Diabetes Vascular Disease* 2002; 2: 272–6.
- 57 Quinlan DM, Epstein JI, Carter BS, Walsh PC. Sexual function following radical prostatectomy: influence of preservation of neurovascular bundles. *J Urol* 1991; 145: 998–1002.
- 58 Haglund E, Carlsson S, Stranne J, Wallerstedt A, Wilderäng U, *et al*. Urinary incontinence and erectile dysfunction after robotic versus open radical prostatectomy: a prospective, controlled, nonrandomised trial. *Eur Urol* 2015; 68: 216–25.
- 59 Van der Wielen GJ, Mulhall JP, Incrocci L. Erectile dysfunction after radiotherapy for prostate cancer and radiation dose to the penile structures: a critical review. *Radiother Oncol* 2007; 84: 107–13.
- 60 Tal R, Jacks LM, Elkin E, Mulhall JP. Penile implant utilization following treatment for prostate cancer: analysis of the SEER-Medicare database. *J Sex Med* 2011; 8: 1797–804.
- 61 Pryor J, Akkus E, Alter G, Jordan G, Lebret T, *et al*. Peyronie's disease. *J Sex Med* 2004; 1: 110–5.
- 62 Montorsi F, Guazzoni G, Bergamaschi F, Consonni P, Rigatti P, *et al*. Vascular abnormalities in Peyronie's disease: the role of color Doppler sonography. *J Urol* 1994; 151: 373–5.
- 63 Mulhall J, Anderson M, Parker M. A surgical algorithm for men with combined Peyronie's disease and erectile dysfunction: functional and satisfaction outcomes. *J Sex Med* 2005; 2: 132–8.
- 64 Pryor J, Akkus E, Alter G, Jordan G, Lebret T, *et al*. Priapism. *J Sex Med* 2004; 1: 116–20.
- 65 El-Bahnasawy MS, Dawood A, Farouk A. Low-flow priapism: risk factors for erectile dysfunction. *BJU Int* 2002; 89: 285–90.
- 66 Ralph DJ, Garaffa G, Muneer A, Freeman A, Rees R, *et al*. The immediate insertion of a penile prosthesis for acute Ischaemic priapism. *Eur Urol* 2009; 56: 1033–8.
- 67 Munarriz RM, Yan QR, Nehra A, Udelson D, Goldstein I. Blunt trauma: the pathophysiology of hemodynamic injury leading to erectile dysfunction. *J Urol* 1995; 153: 1831–40.
- 68 Ramos AS, Samsó JV. Specific aspects of erectile dysfunction in spinal cord injury. *Int J Impot Res* 2004; 16 Suppl 2: S42–5.
- 69 Zermann DH, Kutzenberger J, Sauerwein D, Schubert J, Loeffler U. Penile prosthetic surgery in neurologically impaired patients: long-term followup. *J Urol* 2006; 175: 1041–4.
- 70 Wilson SK, Delk JR, Salem EA, Cleves MA. Long-term survival of inflatable penile prostheses: Single surgical group experience with 2,384 first-time implants spanning two decades. *J Sex Med* 2007; 4: 1074–9.
- 71 Onyeji IC, Sui W, Pagano MJ, Weinberg AC, James MB, *et al*. Impact of surgeon case volume on reoperation rates after inflatable penile prosthesis surgery. *J Urol* 2017; 197: 223–9.

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