Survival into adulthood for individuals with spina bifida has significantly improved over the last 40 years with the majority of patients now living as adults. Despite this growing population of adult patients who have increased medical needs compared to the general population, including spina bifida (SB)-specific care, age-related secondary disabilities, and general adult medical needs, there is little published information about the natural history of SB in adulthood. There are few published studies of medical conditions, interventions, or long-term complications in this population. This article will provide a review of the medical issues of adults with SB, highlighting areas that are different than pediatric care, and areas of needed research.

**Key Words:** spina bifida; adult health care; secondary conditions; developmental disability; health services

## INTRODUCTION

**S**urvival of neonates, infants, and children with spina bifida (SB) has improved significantly and now there is a 50–94% survival rate to adulthood [Bowman et al., 2001; Oakeshott and Hunt, 2003; Davis et al., 2005]. It is estimated that the majority of individuals living with SB are adults [Ouyang et al., 2007]. Despite the predominance of adult patients, less is known about this age group compared to current pediatric patients. It is not meant to be a comprehensive review of adult SB management that has recently been published elsewhere [Dicianno et al., 2008; Webb, 2009].

What is known about adult morbidity, mortality, and secondary complications are mostly from case reports, small case series, and/or single SB tertiary referral centers. There are a few regional studies and centers that monitor larger populations of patients. Some of these centers, both tertiary referral and regional, have followed patients for decades, into midlife. In many of the other case series, the “adult patients” are between the ages of 16 and 25, thus focusing on the transition years between pediatrics and adult medicine. Very little is published about later adult ages, especially those over the age of 40. Because of changes in care over the last 40 years, this older population is likely to be quite different than current young adults due to differences in treatments such as timing of neonatal care, types of ventricular shunting, urinary diversions versus clean intermittent catheterization, and aggressiveness of orthopedic procedures.

The health of adults with SB can vary widely based on age, level of lesion, number and severity of co-morbidities, degree of self-care skills, amount of family and community supports, and access to medical care. The effect of lesion level on SB is well known with higher level lesions having greater impact on neuromuscular function resulting in greater risk for mobility, skin, spine, and cardiopulmonary problems [Hunt, 1999]. Those with myelomeningocele and hydrocephalus are at risk for cognitive difficulties [Dennis and Barnes, 2010], particularly if there were multiple shunt complications [Hunt et al., 1999]. Age impacts health in this population due to the changes in medical management of infants and children with SB over the last generation [Shurtleff, 2000; Bowman and McLone, 2010]. Those born before the mid 1970s will have significantly different health than those born later because both aggressive neonatal care and preventive bladder programs were standard care only after that time period [Dillon et al., 2000; Davis et al., 2005; Clayton et al., 2010]. Before nonelective treatment, only those without significant hydrocephalus who remained unshunted tended to survive early childhood. Similarly, early renal failure was common before catheterization programs. [Davis et al., 2005; Clayton et al., 2010]. Procedures have also changed over time such that ventriculostial shunts, ileal conduits, colostomies, and certain orthopedic surgeries are more common in older adult patients, requiring unique screenings and interventions no longer necessary for current pediatric patients.

This review will examine what is known and uncertain about the health care of adults with SB, emphasizing the differences from pediatric care. It is not meant to be a comprehensive review of adult SB management that has recently been published elsewhere [Dicianno et al., 2008; Webb, 2009].
Areas of uncertainty will be highlighted to underscore the need for additional research.

**GENERAL ADULT HEALTH CARE**

Once adults with SB leave pediatric care, little is known about where they receive services. Occasionally pediatric multispecialty centers continue to follow adult patients or an adult SB center is available, but these practices remain focused on SB–specific issues. In pediatrics, it is assumed that children with SB are most likely to be otherwise healthy and the general care issues are supplanted by the SB–specific care. In adults with SB, other chronic conditions develop that need regular surveillance, including hypertension, hyperlipidemia, diabetes, sexually transmitted diseases, and cancer [U.S. Preventive Services Task Force, 2006]. The prevalence of these chronic conditions in adults with SB and whether there is a difference compared to the general population is not known. In addition, from a health services perspective, there is no information on when or where surveillance for these conditions occurs.

Hypertension is an important example of an adult-onset condition needing a comprehensive approach in SB. Hypertension can be a primary diagnosis or secondary to other medical problems such as obstructive sleep apnea and renal disease, both secondary conditions to SB. High blood pressure was reported in 40% of a small sample of 42 adults with SB over age 35 living in the United Kingdom, but the etiology of the hypertension was not evaluated [Long and Green, 2009]. Hypertension was found in 20% of a small sample of 16–30 year olds with SB in the Netherlands. By comparison, 29% of all U.S. adults, and only 7% of those aged 18–39 have hypertension [Centers for Disease Control and Prevention, 2007]. This same Dutch sample had a 38% prevalence of hyperlipidemia. Overall, 42% of this young adult Netherlands sample had at least two risk factors for cardiovascular disease, with nonambulators having four times the prevalence than ambulators [Buffart et al., 2008b].

Diabetes screening is a standard part of adult primary care but not usually routinely screened in pediatrics. There is some evidence of insulin resistance and metabolic syndrome in teens with SB that raises the concern for later diabetes in adults with SB [Nelson et al., 2007]. There is no study on insulin resistance or diabetes in adults with SB, but the risk factors of obesity and sedentary lifestyle are present [Buffart et al., 2008a; Dosa et al., 2009].

Cancer screening is an important part of routine adult medical care. Women with SB have multiple risk factors for developing breast, uterine, and ovarian cancer, such as early onset menarche, nulliparity, and obesity. Undescended testes may lead to testicular cancer. Obesity may be a risk factor for colon cancer. Despite these known risk factors, which are associated with SB, the relative risks of these cancers in adults with SB are unknown.

Whether adults with SB are at different risk for sexually transmitted infections is unknown; however, small studies have shown less sexual activity among young adults with SB, but those who are sexually active demonstrate riskier behaviors [Cromer et al., 1990; Verhoeof et al., 2005a,b].

**In adults with SB, chronic conditions develop that need regular surveillance, including hypertension, hyperlipidemia, diabetes, sexually transmitted diseases, and cancer.**

**SPINA BIFIDA CARE**

Adults with SB are at risk for the same secondary complications as children, but also have potential health concerns from the longitudinal effects of hydrocephalus, neuromuscular weakness or immobility, neurogenic bowel and bladder, bone and joint deformity, insensate skin, and abnormal peripheral circulation. In addition, there are potential complications from the chronic effects of childhood procedures such as ventricular shunting, urinary diversions, continence procedures, and orthopedic surgeries on spines, hips, and lower extremities addressed in several papers in this issue. Longitudinal studies of procedure outcomes rarely include individuals outside of the teens or early twenties age range.

**NEUROSURGICAL ISSUES**

The three most commonly described issues for adults with SB are shunt complications, tethered spinal cord, and syringomyelia.

**HYDROCEPHALUS AND VENTRICULAR SHUNTING**

Ventricular shunting of hydrocephalus occurs in approximately 80–85% of patients with SB myelomeningocele [Hunt et al., 1999; Müller and Cohen, 2006]. In adults with SB and stable asymptomatic hydrocephalus, there is a general assumption that the shunt is no longer necessary; the patient has arrested hydrocephalus or shunt independence [Bowman and McLoone, 2010]. However, there are small case series demonstrating late-onset shunt failure without classic neuroimaging changes or neurological symptoms [Tomlinson and Sugarman, 1995; Mataro et al., 2000; Edwards et al., 2003]. In one series of 110 patients ages 14–31, 7.5% and 3.5% of the emergent operations occurred in shunts 10 and 15 years old, respectively. There were also five deaths attributed to shunt malfunction, some in individuals under evaluation for subtle symptoms [Tomlinson and Sugarman, 1995].

Typical neuroimaging findings of increased ventricular size may not be present in shunt malfunction. In a retrospective review of 51 headache evaluations in 23 adults with SB and CSF shunts, 52% of those with unchanged ventriculomegaly or normal ventricular size on neuroimaging had confirmed increased pressure during intracranial monitoring. This study also found that headache characteristics often associated with shunt malfunction, such as headache location, early morning onset, and associated vomiting, had positive predictive values of 43%, 54%, and 45%, respectively [Edwards et al., 2003].

Shunt failure has been demonstrated in adults whose only symptoms were changes in neurocognitive function. One small series of adolescent and adult patients believed to have stable ventriculomegaly and no symptoms of shunt malfunction found abnormal pressure waves on intracranial monitoring. In addition, there were significant improvements in neurocognitive function following shunt replacement, particularly in verbal and visual memory, motor coordination, attention, and cognitive flexibility [Mataro et al., 2000].

These small series underscore the need to further examine previous dogma regarding arrested hydrocephalus and to explore the effects of chronic hydrocephalus on cognition.
TETHERED CORD
Like children [Thomson and Segal, 2010], adults with repaired SB myelomeningocele are at risk for re-tethering syndrome. The most commonly reported triggers in adults are falls, back trauma, heavy lifting, and vaginal childbirth [Partington, 2005]. There are no published case series comparing surgical versus nonsurgical outcomes for adults with SB and retethering; however, after surgical unfeathering, pain may not completely resolve and often recurs over time [Retake, 2006]. Conservative, nonsurgical management with nonsteroidal anti-inflammatory medications and even steroid bursts have been anecdotally successful in alleviating exacerbations of pain [Partington, 2005].

SYRINGOMYELIA
Adults with SB remain at risk for developing a syrinx anywhere along the spinal cord. One case series reported a prevalence of 48% of adult patients who underwent MRI of the spinal cord [McDonnell et al., 2000]. As with children, the development of a syrinx may be a manifestation of a shunt malfunction [Retake, 2006.] Syringobulbia is of particular concern and may contribute to sleep disordered breathing and sudden death [Pasterkamp et al., 1989; Kirk et al., 1999]. Whether “asymptomatic” syrinxes cause late-onset problems with neuromuscular or brainstem function is not known.

MUSCULOSKELETAL ISSUES
Once linear growth is complete, there are fewer orthopedic surgical issues like those facing children [Thomson and Segal, 2010]. In adults, the major orthopedic surgical concerns are related to previously implanted spinal rods and chronic degenerative changes or osteomyelitis of insensate limbs or pelvic bones. Chronic or recurrent decubiti leading to chronic or recurrent osteomyelitis may require amputation of the affected limb [Nehring and Faux, 2006]. The frequency of these complications in adults is not known.

More common orthopedic complaints are nonsurgical in nature, including chronic pain resulting from abnormal posture and body mechanics of the back, hips, and legs during ambulation and in the neck, wrists, and shoulders during wheelchair propulsion. In one study of wheelchair users there was less than expected shoulder pain among young adults with SB but there was a non-significant trend towards greater frequency of pain with increasing patient age [Roehrig and Like, 2008].

Loss of mobility is also a concern in adulthood. Retrospective reviews demonstrate that those with lesion levels above L5 are significantly less likely to ambulate by age 30. In one sample of adults >35 years old, 20% of childhood ambulators became wheelchair users [Long and Green, 2009].

While back pain can be a symptom of tethered cord, other de-conditioning and degenerative adult-onset processes may be responsible [Retake, 2006]. The effects of chronic lower body weakness and altered gait can cause musculoskeletal pain in the lower back, particularly if the patient has a Trendelenburg gait, significant pelvic obliquity, or excessive lumbar lordosis. There are no published studies in SB on the utility of medications with indications for neuropathy or fibromyalgia pain. There is some evidence in the spinal cord injury literature of improved pain using certain antiepileptic medications and these drugs have anecdotally been helpful in some patients with SB [Rintala et al., 2007; Tzellos et al., 2008].

OSTEOPOROSIS
Only one study has looked at bone density in adults with SB [Valtonen et al., 2006]. There were 21 subjects (10 females) ages 19–47 (mean 30), including all types of ambulators. Bone density was measured in intact lumbar vertebrae, nondeformed hips, and/or forearms. Thirty-three percent of the subjects had World Health Organization (WHO) defined osteopenia in at least one site. There was a trend towards lower bone density in the femoral neck in nonambulators compared to ambulators, but this did not reach statistical significance. There have been no studies in adults with SB regarding treatment.

CARDIOPULMONARY
Cardiac causes are listed as a cause of death in registry-based studies of adults with SB [Singhal and Matthew, 1999; McDonnell and McCann, 2000], but the mechanisms are not elucidated. The prevalence and relative risk of coronary artery disease is unknown, but the risk factors of obesity and sedentary lifestyle are common in this population [Buffart et al., 2008a; Dosa et al., 2009]. One population study of adults with SB followed for 40 years from birth found pulmonary embolus as a cause of sudden death [Oakeshott et al., 2009]. Another study found an increase prevalence of thromboembolic disease in hospital records, but these were not stratified by procedures and could have been influenced by prolonged immobility due to certain procedures (i.e., spinal rods) performed at high frequency in patients with SB [Levey et al., 2002]. Thus, the risk of spontaneous thromboembolism in this population with decreased mobility remains uncertain.

Individuals with SB appear to have an increased risk for sleep apnea [Luptak and El Samra, 2010]. In infancy, the risk is associated with Chiari malformations [see Jurank and Salaman, 2010, for a description of the Chiari malformations] and is predominantly of the central apnea type [Kirk et al., 1999]. In adults, obstructive apnea becomes a problem (personal data). The exact contributions of low muscle tone, increased neck and chest girth, hydrocephalus, syringobulbia, and Chiari malformation are not known, but the effect of obstructive apnea on increasing intracranial pressure has been anecdotally reported [Pasterkamp et al., 1989]. Whether these pressure changes affect shunt function, as well as how adults with arrested hydrocephalus and non-functioning shunts respond to these sleep apnea effects, are important research questions because reversible treatment is readily available.

OBESITY
Obesity is reported in 35–37% of adults with SB in recent surveys [Buffart et al., 2008a; Dosa et al., 2009]. This prevalence was two to four times greater than preteens and teenagers, respectively. Risk factors include non-ambulatory status, hypoactivity, low lean muscle mass, low basal metabolic rate, and neuroendocrine abnormalities from hydrocephalus [van den Berg-Emons et al., 2003; Roebrock et al., 2006; Buffart et al., 2008a]. In two of the studies, female sex predicted higher body mass index and body fat content, as well as lower aerobic fitness, when controlling for all other factors [Buffart et al., 2008a; Dosa et al., 2009]. Participating in physical activities was associated with improved health-related quality of life but not with lower body fat [Buffart et al., 2009]. Other interventions for obesity, such as bariatric surgery have been anecdotally reported but without long-term follow-up [Mayo et al., 2009]. More research is needed in obesity and SB including reducible risk factors, associated complications, and potential treatments. A major com-
plexity in studying obesity in this population is finding standard definitions and measurement tools in this population with unique upper and lower body habitus.

**SKIN ISSUES**

Skin problems are common in adults with SB. In one survey of adults, 62% had experienced skin problems [Long and Green, 2009]. Decubiti are common reasons for hospitalization and clinic visits [Morgan et al., 1993; Kinsman and Doehring, 1996; McDonnell and McCann, 2000]. Most risk factors are the same as for children [Liptak and El Samra, 2010], including poorly fitting orthotics, incontinence, obesity, prolonged sitting, improper wheelchair seating, venous and lymphatic insufficiency, inadequate nutrition, and weakened tissue in areas of previous decubiti.

Another potential reason for the high prevalence of decubiti is that individuals with SB have smaller blood vessels and slower lower-extremity blood flow compared to the both those without spinal cord dysfunction and those with acquired spinal cord injuries. In addition, the vascular wall shear stress is higher in SB that may lead to endothelial damage [Booth et al., 2003]. This is of even greater concern for the 19% of smokers in the Netherlands survey of young adults with SB [Buffart et al., 2008b].

**LATEX ALLERGY**

Adults with SB, like children, are at higher than average risk for reacting to latex, with an average prevalence of 40% on testing and 15% having clinical symptoms on exposure [Ausilli et al., 2007]. There continues to be debate on the contributions of shunt status, number and timing of surgical procedures, age, and family history of atopy [De Swert et al., 1997; Niggemann et al., 1998]. There is no indication that the responses to exposure or treatment protocols are different for adults, except that older adults are more likely to have had repeated latex exposures before latex recommendations were common.

**UROLOGICAL ISSUES**

Adults with SB continue to have neurogenic bladders. Depending on their age, they may or may not have been on lifelong clean intermittent catheterization (CIC) programs, which were introduced in the 1970s [Clayton et al., 2010]. Studies of adults born before aggressive bladder care documented a prevalence of renal abnormalities of 41% [Ahmad and Granitsiotis, 2007]. The risk of renal failure in older adults with SB can be eight times greater than the general population, particularly for those who have a urinary diversion procedure such as an ileal conduit [Ahmad and Granitsiotis, 2007]. Most of the renal failure prevalence is reported in older populations who did not do CIC, in patients with urinary diversion procedures, and those not adhering to CIC [McDonnell and McCann, 2000; Ahmad and Granitsiotis, 2007]. In populations of patients who are closely followed in their SB clinics renal failure is uncommon [Bowman et al., 2001]. Survival rates for individuals with SB and renal failure on dialysis are reported as 94% at 1 year and as good as 82% at 5 years. Overall, it appears that survival on dialysis, as well as survival after renal transplantation, is equal to those without SB [Ahmad and Granitsiotis, 2007].

Bladder cancer is an adult-onset complication for neurogenic bladder. Transitional cell cancer, squamous cell cancer, and adenocarcinoma have been found on cystoscopy as early as 8 years after augmentation. The median age in one study was 37 years old, and almost all were advanced stage at diagnosis [Austin et al., 2007]. Only 7 of the 19 cancers were in patients who had a bladder augmentation. Smoking was not found to be a major factor in this study. The contribution of risk by chronic bacteriuria, type of catheterization and augmentation procedures, and long-term use of antibiotic suppression is not known. More research on the risk factors and natural history of cancer in neurogenic bladders with and without augmentation is needed.

**BOWEL ISSUES**

Abnormal bowel function is present in most adults with SB. Sixty-eight percent of adult clinic attendees in Belfast reported abnormal bowel function [McDonnell and McCann, 2000]. Problems included constipation, urgency, frequency, incontinence, and hemorrhoids. There was a significant increase in fecal incontinence among 179 young adults surveyed in the Netherlands despite bowel programs that included special diets, laxatives, stool softeners, retrograde enemas, suppositories, and manual disimpaction. None of the bowel programs demonstrated significantly superior results [Verhoef et al., 2005a,b]. The antegrade colonic enema (ACE) procedure, now commonly used in pediatrics, was not reported in these adults. Half (46%) of the adults in this study did not have any type of bowel program. In one longstanding U.S. clinic, only 38% of the patients reported having a bowel program, but the majority report bowel continence at least 75% of the time [Bowman et al., 2001]. The types of bowel programs were not reviewed.

The long-term effects of the different types of bowel programs are not known. Only long-term use of anthraquinone laxatives like senna is known to cause changes in the colon that may lead to adenomas. The long-term utility of the surgical options, like the ACE procedure, has been raised, but comparative studies have not been performed [Yardley et al., 2009].

**SEXUALITY AND REPRODUCTIVE ISSUES**

Aside from early-onset puberty and menarche in women with SB and hydrocephalus, there are limited studies of gynecologic issues in these patients. The few articles published often combine women with SB, spinal cord injury, and multiple sclerosis. While the neuromotor and musculoskeletal challenges are similar in these groups, the differences are significant, especially the effects of congenital hydrocephalus on neuroendocrine function and the abnormal fetal development of the neurologic system in SB.

While there are no published reports of abnormal menstrual cycles in adult women with SB, the challenges of immobility and contractures on menstrual hygiene are known [Jackson and Mott, 2007]. Neuromuscular abnormalities impact sexual activity, especially positioning and sensation. Sexual functions such as lubrication and orgasm depend on the level of the neurological impairment [Jackson and Sipki, 2005].

Women with SB are believed to have normal fertility and at least 70% of those who conceive have successful pregnancies [Jackson and Mott, 2007]. The gravid uterus can adversely impact balance and ambulation, ventriculoperitoneal shunt drainage, neurogenic bowel and bladder function, urinary or colon conduit and stomal patency, skin integrity, and pulmonary function, particularly with significant co-morbid kyphoscoliosis.

Cesarean sections are common due to the neuromuscular changes of the perineum and contractures of the hips and lower extremities.

Pregnancy outcomes are generally good, with some reports of congenital abnormalities [Natarajan et al., 2002].
There is a known 4–7% prevalence of offspring with SB and a proven risk reduction with high-dose folic acid supplementation (4–5 mg daily) prior to reduction with high-dose folic acid supplementation. Offspring with SB and a proven risk of osteoporosis, incontinence, uterine prolapse, and decubitus ulcers for this population [Jackson and Mott, 2007].

Men with SB have issues with erectile dysfunction, anorgasmia, retrograde ejaculation, and azospermia [Woodhouse, 2005; Bong and Rovner, 2007]. As expected, the higher the neurological lesion level, the less likely to have typical function. Psychogenic erections and ejaculation are preserved at higher lesion levels than erections by tactile stimulation or orgasms during ejaculation [Shiomi et al., 2006]. Side-effects have been shown to help men with SB and erectile dysfunction in a dose-related response [Palmer et al., 2000]. None of the other selective phosphodiesterase-5 inhibitors have been studied. Fertility procedures are offered to men with SB, but outcomes are not studied.

FUTURE RESEARCH

More research in adults is needed to better understand the late-onset secondary conditions associated with SB and the longitudinal effects of childhood procedures. As several papers in this special issue document, there are important research topics in each discipline; however, the three areas with the most immediate impact would likely be ventricular shunts, neurogenic bladders, and sleep apnea. Late-onset shunt failure is implicated in the sudden death of adults with SB. In addition, subtle shunt failures may cause cognitive impairments which affect self-management and independence skills.

Understanding the long-term effects of daily catheterization, intestinal augmentation, and chronic bacteruria on neurogenic bladder mucosa and kidney function will also impact survival by identifying modifiable risk factors. Determining which bladder management program is best for long-term kidney function can decrease morbidity and mortality. Also important is to better understand the risks of cancer in neurogenic bladders. Finally, improving continence will positively impact independence and employability.

Sleep apnea is likely to be more prevalent in adults with SB than currently recognized. It is possible that sleep apnea has effects on shunt function, cognitive impairments, insulin resistance, obesity, and cardiopulmonary problems in this population, as there have been associations found in the general population. Identifying and correcting sleep apnea will likely positively impact morbidity, mortality, and quality of life.

To study these research questions, greater numbers of subjects are needed. Multisite investigations with adequate sample sizes are necessary to confirm the findings reported in the small studies reported in this article. Future research would benefit from standardizing terminology and outcomes (i.e., how is obesity defined and measured in non-anambulatory subjects with and without underdeveloped lower extremities, or what is the standard definition of urinary and fecal continence), thereby allowing accurate comparisons across studies. Finally, inclusion of adult patients in the 4th, 5th, 6th and even older decades of life is needed to examine the natural history of SB and long-term outcomes of medical interventions. Any study in this age group will be difficult until these adults are treated in dedicated multidisciplinary SB clinics and centers similar to those serving the pediatric population.

CONCLUSIONS

Adults with SB continue to have increased medical needs compared to the general population. Medical complications include typical SB concerns similar to pediatric patients, but also conditions due to long-term aberrations of normal neurological, urological, and musculoskeletal function. Research that includes only adults with SB, including middle-aged patients, is necessary to understand the late secondary conditions of SB and the longitudinal effects of childhood procedures, such as ventricular shunting, bladder augmentation, urinary diversion, tendon transfers, and spinal rods.

REFERENCES


