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Obesity and Spinal Disease

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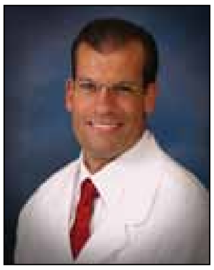

From the Editor

Brian R. Subach, M.D., F.A.C.S.

Obesity and Spinal Surgery

Many people gain weight due to inactivity and slowing metabolic demand as we age. Often, patients with spinal disease will experience pain when increasing activity, making it even harder to maintain a healthy weight. Dieting is only effective to a point. We need to actually burn more calories than we consume. For many people, obesity can become a progressive and debilitating condition.

I am commonly asked in the office about the relationship between weight gain and low back pain. It seems reasonable that losing weight should reduce back pain by decreasing the amount of stress on the discs and ligaments of the spine. When you are above your ideal weight, your muscles need to work harder to accomplish everyday tasks. Adding weight to the front of the spine (abdomen) can cause malalignment and increased strain on the supporting low back musculature. The North American Spine Society recommends staying within ten pounds of your ideal body weight to keep your back healthy. While research has yet to find a direct causal relationship between obesity and back pain, both patients and spinal health care providers strongly believe in the association. Increasingly, health care professionals are directing their patients toward making more sensible choices, such as maintaining a healthy and active life style as a means of managing and preventing back pain.

This is extremely relevant to my practice. Researchers from Thomas Jefferson University found that the risk for surgical complications increases relative to the degree of patient obesity. In other words, the higher your body mass index (BMI) the greater the chance you will experience problems related to your surgery. This goes for all surgical procedures, not just spinal surgery. One study found a complication rate for surgical patients of a healthy weight to be approximately 14%. For those with a BMI greater than 40 (normal range is 18.5 -25), the complication rate jumped to greater than 36%. In particular, complications associated with spinal fusion patients with high BMI's are a concern for spinal surgeons. The American Academy of Neurosurgeons states that in surgeries done to relieve low back pain, the failure rate for patients whose BMI is over 40 is significantly increased.

Many times wound healing is the primary complication associated with obesity. When someone is obese, he or she may have a disorder of metabolism or simply a poor nutritional condition. The lack of adequate protein and vitamins in a person's diet can often compromise wound healing. The American Academy of Neurosurgeons also notes that pneumonia, deep venous thrombosis (blood clot), and the need for additional surgery are common in this population. As in any type of surgery, there are a number of possible problems related to anesthesia. The sedation used in anesthesia can cause decreased respirations (slow or shallow breathing). This can make it more difficult to properly exchange oxygen and carbon dioxide from the bloodstream. Combining this with the extra weight of the chest wall in an obese person, makes it more difficult for the lungs to function properly. This can dramatically increase the rate of post-operative pneumonia.

Along with maintaining a healthy diet that restricts caloric intake, engaging in regular physical activity is crucial to achieving one's ideal weight. The good news is that physical activity itself also helps manage back pain. Studies looking at recreational activities show that fit people in general have less back pain. Experts generally agree that exercise is often the best way to treat and prevent chronic low back pain.

In summary, obesity not only causes problems with general health status but specific problems with the spine. With poor posture and additional weight loading the spine, many people develop chronic and progressive low back pain. This issue is dedicated to the facts and science of the relationship between obesity and spinal disease.

From the President
Thomas C. Schuler, M.D., F.A.C.S.

The Only Way to Cut Healthcare Costs is to Ration Healthcare

The purpose of the Spinal Research Foundation is to improve spinal health care for all Americans. It is my opinion that the current health care reform proposals will be detrimental to the quality and the availability of spinal health care in these United States.

Currently, the United States health care system is under attack by the Government and the media. Individuals and organizations with a strong agenda to institute a single-payer health care system, continue to allege that the United States health care system is substandard. To support their false accusation, they quote inaccurate and somewhat irrelevant data. They cite life expectancy data and infant mortality data, without explaining the methods and biases in these data.

The United States has the best health care in the world. We currently spend more money on health care, as a percent of our GDP, than any other nation in the world. The United States has the finest health care institutions in the world; physicians travel here from all over the world for advanced training and patients come from all over the world to receive our outstanding health care. The problem that we have in our country is access to health care for all individuals. Emergency health care is available to everyone just by going to an emergency room. Elective health care is more difficult for the 15% uninsured in the U.S.

In a meeting I had with Senator Mark Warner recently I questioned, "How do we maintain the excellent quality of health care that we have in the United States while providing more care to more individuals and at the same time control costs?" His answer was, "We do not have the best quality health care in the world, based on the life expectancy data and the infant mortality data." He also stated that, "The end of life expenditures, which also accounts for 50% of an individual's health care dollars spent during their lifetime, needs to be controlled" (rationed).

Senator Warner's comments illuminate the problem which we Americans have in protecting our health care system. The senator, his colleagues and the media are continuously quoting data which is misleading and inaccurate. This is not to say that there are not issues that need to be addressed in the United States health care system, but the direct attack on the future of health care for Americans is something that will affect every one of us throughout our lives. The only way to lower the cost of health care is to ration health care.

The current administration claims that preventative health care is one of the routes to health care savings. In fact, this could not be further from the truth. Preventative health care is important, but international data has confirmed that, at best, it is cost-neutral to the overall system. Preventative health care costs money to deliver, takes resources to deliver and requires that a recipient, the patient, is willing to proceed with the care. To support the fact that free access to preventative health care does not change the treatment rate of disease, we need to look no further than the United Kingdom, where there is a single-payer system. If we look at the frequency of undiagnosed diabetes, specifically one out of every two people with the disease, it is the same in the United States as it is in the United Kingdom. The availability of free preventative health care does not change the disease pattern. The three most common health problems in the United States are obesity, deconditioning and smoking. Preventative health care for all three of these is widely available; eating a healthier diet, exercising and stopping smoking. However, as the incidents of each of these chronic illnesses is increasing, not decreasing in the United States, it is hard to argue that free access will solve these problems. In fact, it is possible that universal access to "free" care may actually make preventative care less available. If the goal of the administration is to limit the expenditures of health care dollars, then the only way to do that is

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to ration care and to limit access to advanced medical testing and treatment.

Currently, the United States does extremely well in preventative health care as compared to other countries. If we look at the International numbers for "potential years of life loss" per 100,000 population, which is a measurement of the numbers of years lost due to a lack of preventative care, the United States ranks number two in the world for years of life saved by preventative care. This is well above most single-payer systems. The administration claims that preventative care will produce funding to support health care for all Americans, when in fact this couldn't be further from the truth.

Life expectancy, by some, is considered to represent the strength of the health care system. The problem with using this number as a basis for determining health care is that it does not take into account genetic factors. Specifically to this point, Japan has an average life expectancy of 80.6 years, which is the highest of any nation in the world. The population of Japan is genetically very homogeneous. The United States has an average life expectancy at birth of 76.7 years. However, the United States is one of the most ethnically diverse countries in the world. Japanese-American life expectancy mirrors that of their homeland. What we know from all areas of medicine is that genetics is the strongest predictor of the development of health disorders. Our country has been made great by being made the melting pot of the world, but this does come with some costs, specifically, life expectancy averaged from our diverse genetic heritage.

Infant mortality is often touted as a basis for judging the quality of health care in a country. The United States has 6.8 infant mortalities per 1,000 births. Sweden and Japan rate the lowest at 3.6 infant mortalities per 1,000 births. Many other countries rank in between these numbers. The problem with this data is that there is no standardization as to how to tabulate this data. Many countries do not report babies born at twenty-five weeks of gestation or babies weighing 1.5 pounds at live birth. The United States has pioneered the delivery and treatment of premature babies. Since the United States has been the leader in the development of these technologies, we have accurately and completely recorded all infant mortality. It should be further noted that the data for whites in the United States is similar to that of Western Europe, which supports that perhaps a problem in the United States is not the quality of health care, but the distribution of health care. It is also noted that countries in the industrialized world that frequently have the best outcomes are, for the most part, quite ethnically homogeneous. Sweden, Norway, Iceland, France, Italy, and Japan, generally rank very well, but are much more homogeneous than the ethnically and culturally diverse United States. Currently, 44% of the U.S. is non-caucasian. This number is projected to increase to greater than 50% over the next several decades.

Also of significance, is the fact that the high school drop-out rate in the United States is well above 20%, which is one of the highest drop-out rates in the industrialized world. Students who drop out are more likely to be unemployed, unable to obtain health insurance, skip prenatal care with pregnancies and have poor personal health habits (for example; diet and exercise). Although this is an extremely important problem, it is not a problem created by the United States health care system, but nevertheless places tremendous stress on the health care system.

The bottom line reveals that the modest ranking of the United States in life expectancy and infant mortality statistics is not attributable to the performance of the United States health care system, but to a variety of other factors.

Massachusetts has pioneered a reform to try and ensure the health care coverage of all its citizens and this has proven to cost considerably more than projected. To manage these costs, the State legislators are discussing the concepts of more aggressively excluding certain services, further regulating reimbursements, and limiting costs. The end result will be that physicians in Massachusetts will be unable or unwilling to provide services when the patients want it and how the patients want it. This leads one to conclude that health care must be rationed to limit costs.

I believe that Americans are not willing to give up the best health care system in the world. Americans have come to expect to receive the finest quality health care provided when they want it. Is someone willing to live with intractable pain for one week, one month, or even one year while awaiting Government authorization for a procedure? Or worse, having the Government state that their procedure is not allowed? Spinal health care is at the forefront of the Government's cost cutting and rationing agenda. Much of spinal health care treats pain and improves quality of life. These services, by the nature of their complexity and high risk, are expensive. The Government considers pain relief to be less than essential. Once again, the way the Government plans to balance the health care costs is to eliminate care.

Access to care remains an issue for some Americans. The uninsured, according to the United States Census Report 2007, tallies 45.7 million. But if we dissect these numbers, we realize that the number of uninsured in the United States has been constant at 14 to 15% of the population under the age of 65, for the past 20 years. Of the uninsured, many are only uninsured for a few months between jobs. 9.7 million of the uninsured are illegal immigrants. 14 million of the uninsured fall below the poverty level and are actually eligible for Medicaid, but have not applied for it, either intentionally or unintentionally. 18 million of the uninsured have a household income of more than $50,000 per year, and of those, 9 million have a household income of more than $75,000. Of the uninsured, 11 million have been offered insurance through their employer, but have declined. These individuals are typically young people who choose not to spend their money on health insurance they believe they will never need. All in all, 70% of the uninsured actually have access to health insurance, but have not taken advantage of it.

The Government's goal is to create a system which will insure everyone and cap costs. The problem with this is that the only way to provide health care for everyone and to cap costs is to limit the health care available to those who are currently receiving the best quality health care. If the United States is to provide comprehensive coverage to all individuals without raising costs, then there must be a decrease in quality and availability for the 85% who currently receive the finest health care in the world. Even if this is not the initial version of the plan, this must be the end result.

Once a Government-based plan is established, employers will rapidly covert their health care coverage to the Government Health Plan to remove a liability and eliminate headaches for the business. Once this Government-based system has enough mass, financial forces will eliminate the private-payer system and the Government system will become a single-payer system. Once the Government-run, single-payer system is in place, the rationing will follow and we will be at a point of no return.

Ask the Expert

Paul J. Slosar, Jr.,M.D.
SpineCare Medical Group

How does my weight affect my back pain?

Generally speaking, personal health can be significantly influenced by your weight. Weight also has a particular impact on spinal health. Obesity can often lead to back pain as the result of a larger load and pressure on the musculoskeletal system, particularly on the lumbar spine. Your body may assume the burden, but not without cost. Over time, deformation of the spine occurs often resulting in conditions such as sciatica and degenerative disc disease. Obesity also impacts the degree of success of your spinal treatment. Studies show that higher Body Mass Index (BMI) results in greater frequency of perioperative complications such as wound infection, cardiac events, and blood clots.

What lifestyle habits do you recommend to maintain a healthy back?

To maintain a healthy back, one should adopt a healthy diet and engage in regular physical activity. Specific exercises can also help strengthen your spine, but you should always consult your doctor before starting a new exercise program, especially if you have back pain. In addition to diet and exercise, it is important that you adopt certain habits in order to prevent back pain. Sleep on a firm mattress instead of a soft one because your body may contort, creating the potential for unintended stress on your spine. Be sure to walk around after sitting for prolonged durations of time. Practice good posture and correct lifting techniques. Wear soft-soled shoes because the extra cushioning absorbs the stress placed on the back. These lifestyle changes will increase the chances of maintaining a healthy back.

Can losing weight really reverse the degenerative process?

When patients are significantly above their ideal weight, their back muscles often must work harder to perform daily activities, contributing to the onset of back pain. Excess weight can also cause spinal misalignment. Though there has been minimal research on the link between back pain and weight loss, many patients who lose a significant amount of weight experience dramatic reductions in back pain. Think of the hiker burdened by a heavy backpack, largely supported by his lower spine while hiking. As soon as the hiker throws off his pack, there is less pressure on the spine and his posture returns to normal. The same principle applies to weight loss.

What BMI is optimal to maintain in order to help decrease my pain?

The optimal Body Mass Index (BMI) ranges from 18.5 to 25 kg/m^2. Above this range, a person is considered overweight. However, BMI measures the weight of muscle mass and fat tissue and does not distinguish between the two. Measuring a person's body weight does not take into account the distinction between muscle mass and fatty tissue. Maintaining a healthy lifestyle through diet and exercise can help keep the pounds off and BMI at a normal level. Therefore, safely losing weight may reduce back pain as well as improve virtually every aspect of health.

Equation for Calculating BMI

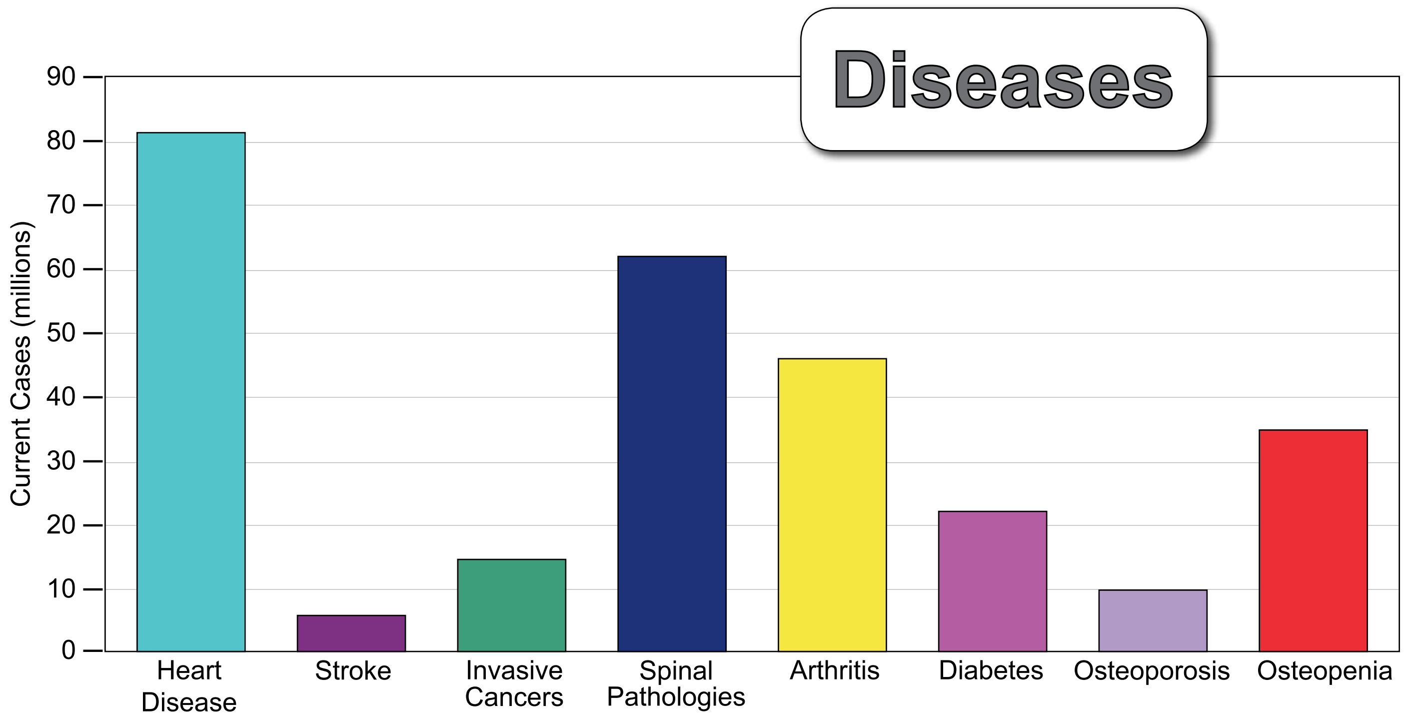
$$\frac{\text{Weight in Pounds}}{(\text{Height in inches}) \times (\text{Height in inches})} \times 703$$

Paul J. Slosar, Jr., M.D.

Dr. Slosar is the president of Orthopedic Spine Surgery at The SpineCare Medical Group in San Frasisco, CA. He has been in practice since 1994 and with the practice since 1997. Dr. Slosar is also Co-director of The San Francisco Spine Institute Surgical Fellowship training program and Assistant Director of Surgical Research. He is a member of the North American Spine Society and has served on editorial research commitees.

According to the National Institutes of Health

- At some point, neck or back pain affects an estimated 9 out of 10 people. It is one of our society's most common medical problems.
- The first attack of neck or low back pain typically occurs between the ages of 30 and 40.
- Spinal pain becomes more common with age.
- With symptoms ranging from a dull ache to absolute agony, back pain can put your life on hold.
- In fact, it is second only to the common cold in causing missed workdays for adults under age 45.
- Office visits for low back pain: 25 million per year
- Medical admissions for low back pain: 325,000 per year



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Diabetes- http://www.diabetes.org/about-diabetes.jsp
Osteoporosis- http://www.nof.org/osteoporosis/diseasefacts.htm
Cancer- National Cancer Institute 1975-2005 statistics.

Spine Tale

As you all know, Spine Tale is a section of the Journal dedicated to patients who have overcome their spinal health problems. In most cases, these folks have initially presented with neck or back pain or progressive nerve damage involving the arms or legs, which take them away from their families, their jobs, and their lives. We have chosen Amy and Paul Mullis as our Spine Tale for this issue. This husband and wife team have triumphed over disabling spinal issues together and have recovered to lead full and functional lives.

Amy Mullis is an attractive forty-two year old woman who initially came to see Dr. Subach in July 2008. This very busy computer engineer had intermittent neck pain and arm symptoms after an accident in 1995. Up until December 2005, she had been treated successfully with chiropractic manipulation and acupuncture. Unfortunately, she began to develop severe migraines. She could barely hold her head upright and had such severe and unremitting pain in her right arm, she had difficulty lifting it. After a fusion across one of her cervical discs in June 2006, she did notice some relief. The relief was short-lived because after approximately three months, the pain started to come back. Although she had pain, she remained relatively functional until she had another motor vehicle accident in May 2008. Looking at her imaging studies, it appeared that the fusion at C5-C6 had never healed properly and the adjacent level, C4-C5, had now started to fail. Essentially, this young woman had two levels of cervical disc degeneration causing severe neck pain with radiation toward the right shoulder.

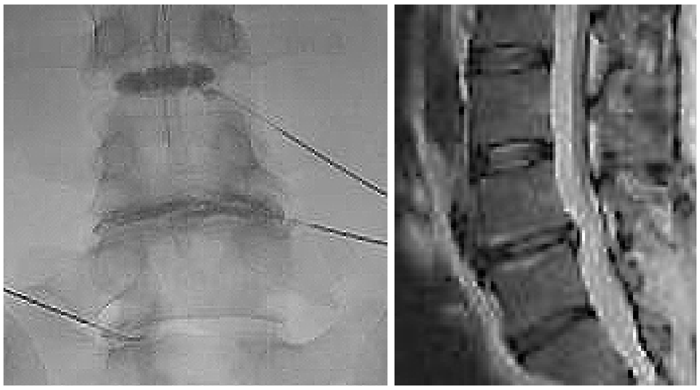
Amy was taken to the operating room on October 6, 2008 where the previous fusion was revised and a new fusion performed at the C4-C5 level. She had bone morphogenetic protein (BMP) placed into each of the two disc spaces along with a small piece of donor bone and a titanium plate across the front of the spine. Immediately after surgery, she knew that things were different. By January 2009, she was showing steady improvement. By March 2009, her pain level was steadily decreasing and her imaging studies showed signs of progressive fusion. Amy had experienced two side effects of cervical fusion surgery; the first was a nonunion (failed fusion), which had not been recognized, and the second was the development of adjacent segment disease due to the transfer of stress from a damaged level. At this point, she is now nine months out from previous surgery and appears to be making steady progress in terms of healing on x-ray and regaining control of her life.

Compressed tomographic image reco nstructions showing incomplete healing of a cervical fusion implant

Lateral X-Ray after Revision Cervical Fusion with BMP Fixation

Amy's husband, Paul Mullis, was first seen on November 6, 2008. Prior to surgery, this thirty-seven year old professional had been having low back trouble for the past ten years. He felt that his symptoms continued to worsen over time despite having undergone previous lumbar laminectomy surgery. He described his pain as 90% in the back and 10% in the leg. On an average day, his score was 6 on a pain scale of 1 to 10 (10 being the worst possible pain). He felt the pain running down the lateral aspect of his left leg and into the left calf and felt that activity made his symptoms worse. Before surgery, his symptoms were terrible when he woke up first thing in the morning. His pain grew worse with activity, and even awakened him from sleep. In general, this very active thirty-seven year old who used to enjoy martial arts, swimming, and hiking was unable to perform any of these activities secondary to the severity of his pain. Based on his level of physical fitness, we did not recommend further physical therapy; rather we recommended additional studies in an attempt to identify his problem.

He first underwent a diagnostic procedure called lumbar discography in which small needles were placed into the degenerating discs of his lumbar spine. Although the magnetic resonance imaging (MRI) scan showed signs of degeneration, this test is performed to correlate one's pain with the abnormalities seen on the MRI. The discography identified the two lowest levels of his lumbar spine to be severely diseased and responsible for his pain. After careful discussion with the patient and his wife, we decided to pursue fusion surgery for the lumbar spine. He underwent a staged procedure in which an anterior lumbar fusion (ALIF) was carried out at the two lowest discs, and then a day later he underwent a posterior lumbar fusion (PLF) using small screws with plastic, flexible rod technology. Two weeks after the surgery, he was sore but already knew he was on the road to recovery. He was tapering down his pain medications and was pleased with his progress after surgery. By May 2009, he essentially had no back pain and very few leg symptoms. His



Lumbar Discography and Magnetic Resonance Imaging showing severe disc degeneration in the lowest two discs.

pain level was down to a 2 on the pain scale ranging from 1-10 and he was returning to normal activities. By June 2009, four months out from his lumbar fusion, his imaging studies showed signs of progressive healing. He had no leg pain and was back to nearly all of his activities.

Lateral Lumbar X-ray after circumferential fusion

Amy and Paul Mullis have undergone significant trials in order to return to the regular activity of their former lives. Amy first underwent an unsuccessful fusion attempt of the cervical spine and then developed adjacent segment disease. This required a cervical fusion procedure which incorporated both diseased levels, restoring her posture and alignment while stabilizing the spine. Her surgery incorporated two of the most advanced cervical fusion technologies, recombinant human BMP and a titanium plate with hybrid screws. Paul's ordeal involved severe degenerative changes in his lumbar spine, which failed to respond to the usual nonoperative treatments. Imaging studies identified the pain generators and he underwent a combined anterior and posterior approach to fusion of the lumbar spine. By coming through the abdomen and then going from the back side, we were able to reconstruct his spine, restoring posture and height where it was lacking. The anterior fusion minimizes damage to the next disc above and the use of a flexible polymer PEEK (polyether-etherketone) rod truly represents cutting edge technology. The Mullises have made excellent progress and realize that the healing process takes time. In general, it may take a year for the spine to finish healing. They have maintained a positive attitude and have been outstanding patients through it all. It is for this reason that we have chosen Amy and Paul Mullis as our Spine Tale

"We've Got Your Back" Event Review

by Sherry McDaniel

Once again, The Spinal Research Foundation's 2009 "We've Got Your Back" Race/Walk & Spinal Health Fair continued its quest for spinal health. Spinal disease can have a debilitating effect on people's lives, oftentimes interfering with many activites in a person's daily routine. Simple tasks such as walking a few blocks, driving a car, or even getting out of bed in the morning can be painful. Nine out of ten people are affected by back and neck pain at some point in their lives.

In the community of Reston, Virginia, on May 16th, 2009, the second annual race began with over 500 hundred participants in attendance. Many of those participants had suffered through back and/or neck problems at one time in their lives. Many of those attending are the friends and family of those who have suffered as well. Emotions ran high as participants were cheered on towards the finish line. To them, this inspiring journey to achieve the goal of walking or running this race meant a lot to them. This year's event also succeeded in educating the public about the latest research, technologies and options for those who suffer from spinal conditions.

Honorary Chairs for the Reston event were Washington Redskins football players James Thrash and Reed Doughty and Olympic Track Cyclist Gideon Massie. Delegate Chuck Caputo of Virginia's 67th district also made a guest appearance to cheer on the participants and support the cause.

The Spinal Research Foundation has taken the first steps to bring this inspirational event nationwide. This year, a second "We've Got Your Back" race was held at Tyler State Park in Newton, PA on June 14th, 2009. Over 200 participants showed up from the Philadelphia Metro area to raise awareness and further our cause. Presenting Sponsor for this event was Princeton Brain and Spine. Honorary Chair for the event was Mike Quick, All-Pro wide receiver of the Philadelphia Eagles. Special thanks to all of our sponsors and donors for their patronage and all race volunteers for their hard work. Without all of you, this event would not have been possible

We've Got Your Back

4 Mile Race - 2 Mile Fun Walk - Spinal Health Fair

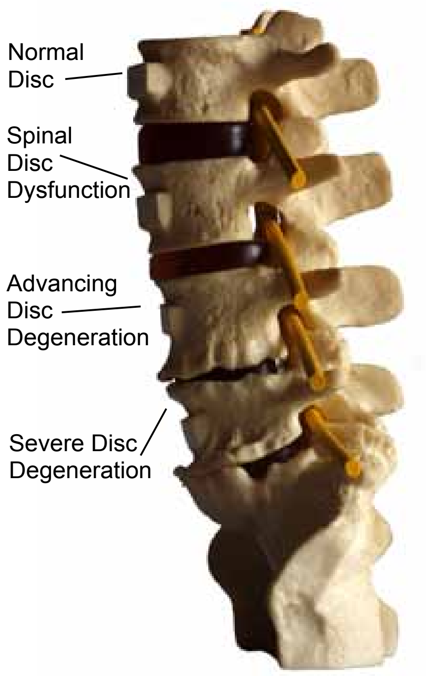
Obesity and Spinal Disease

Anne G. Copay, Ph.D.

According to the American Obesity Association, 64.5% of Americans, about 127 million, are considered either overweight or obese. Obesity has emerged as a major health problem in the United States in the last three decades. Many other countries have also been affected, leading the World Health Organization to deem the situation a global obesity epidemic.[1] Obesity has been associated with increased risk of several cardiovascular, nervous and musculoskeletal conditions.

In a May 2005 survey by the North American Spine Society, 87% of spine care professionals agreed that obesity plays a significant role in back pain. Several topics related to obesity and spine disease are covered in the current issue. Our special focus section begins with an article on obesity and spine surgery by Michael Bradish, M.D., an anesthesiologist at Reston Anesthesia Associates, which provides insight into the specific challenges that arise when performing surgery on obese individuals. Leah Carreon, M.D. of the Kenton D. Leatherman Spine Center then presents a review of the effect of obesity on the outcome of lumbar fusion surgery. This article is followed by a review written by Dr. Eric Pinnar, the Chief, Department of General Surgery at Reston Hospital, and examines bariatric surgery as an option for obesity treatment. Next, Dr. Amy Powell analyzes the effect of bariatric surgery on bone health. Some potential causes of the obesity epidemic are explored by Genevieve F. Dunton, Ph.D., M.P.H. and Casey Durand, M.P.H. In their article they examine the ecological conditions affecting obesity. Treatment strategies involving diet and physical activity which foster proper spine health are addressed in the articles by Danielle Omar, R.D. and Michael McMurray, D.P.T. These two articles outline the safest method of weight loss and spine preservation, which is a combination of diet and exercise. The special focus section contains a brief examination of Body Mass Index and the limits of its accuracy, while highlighting other methods to determine body composition. This section was written by the 2009 SRF Medical Sciences Research Award recipient, William J. Kemp, III. These articles are all provide information on the effect of obesity on the spine and some strategies for the reversal of this condition. The following briefly highlights some specific spinal conditions which may be caused or aggravated by obesity.

Though the exact mechanisms of action have not yet been established, a strong correlation has been found between obesity and disc degeneration, disc herniation, spondylolysthesis, spondylolysis and osteophyte formation.[3,4,5,6] Obesity may affect spine deterioration in two major ways: mechanical stress created by the added body weight and biochemical pathways activated by cytokines produced by excess adipose tissue.[7] Obesity produces an increase in the load on the spine and its supportive structures, such as spinal ligaments. This is more prominent in the lumbar spine which supports the weight of the upper body. Extra loading in the spine has been experimentally shown to speed up disc degeneration, leading to disc herniation or osteophyte formation.[3,8,9] Obesity also affects the stability of the spine by changing the center of gravity of the body and the load distribution of the spine. The force exerted in the lumbar spine dramatically increases when weight is added anteriorly or laterally to the pelvis. Excess belly fat causes increased lumbar lordosis, which combined with the previously mentioned conditions, could lead to spondylolisthesis. Animal experiments reveal that fatty tissue does not only represent extra weight and a source of mechanical stress on the bones, but also a source of



cytokines which may affect several inflammatory and metabolic processes in the body. The production of inflammatory mediators, called adipokines, by fat cells may cause damage to the disc tissue and bone, causing the spine to degenerate. Obesity is indeed associated with a pro-inflammatory state, non-alcoholic fatty liver disease and reproductive disorders, as well as several cardiovascular, nervous and muscular-skeletal conditions, insulin resistance, dyslipidemia and hypertension. This group of obesity related complications characterizes metabolic syndrome.[10]

Disc Degeneration

Disc degeneration refers to the weakening process of the integrity of the spinal discs. Inter-vertebral discs naturally age over time as a result of different biochemical and structural changes.[9] Obesity is one factor which may accelerate the progress of this condition.[11] The spinal discs are designed to tolerate the pressure of the load on the spine and may break down under excessive load. Tests performed on animal models using devices to compress the spinal discs demonstrate that an increase in the compressive stress on the discs, over time, causes a general deterioration in the load-bearing capacity.[11] An excessive amount of body fat may cause added spinal stress.

Disc Herniation

Excess weight may also increase the risk of disc herniation. Discs may start to degenerate due to the greater mechanical load placed on the spine and it is more likely to bulge or rupture. The deteriorated annulus in combination with the added pressure on the disc nucleus may force the disc material to be extruded, resulting in a disc rupture or herniation. Studies performed by Lean et. al. demonstrate that symptoms of a disc herniation were 1.5 times more likely in women with a BMI over 30kg/ m^2 than in women whose BMI was less than 25 kg/m^2. [12] The extra load placed on the spine of an obese individual causes the spine to lordose. This extra lordosis could contribute to degeneration of the outer fibers of the disk. Over time this can result in tears or even complete vertebral annular rupture.

Spondylolisthesis

Obesity often leads to an alteration in the posture of patients, causing an increase in lumbar lordosis and added mechanical stress to the disc. This may happen in cases where patients have a significant amount of belly fat. The degenerated disc and altered posture may weaken the intervertebral disc and encourage the upper vertebra to slide forward resulting in spondylolisthesis. Evidence obtained from the Copenhagen Osteoarthritis Study illustrates that lumbar degenerative spondylolisthesis in women was significantly associated with high BMI.[13]

Spondylosis

Spondylosis is the degeneration of the articulation points of the vertebrae. Spondylosis of the lumbar spine appears to be associated with an increase in the forces exerted on the spine. Weight gain causes additional loading stress on the spine, which may result in spinal instability and spondylosis.[14]

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Osteophytes

Degenerated spinal discs in the spine often have a reduced ability to bear the spinal load. Greater tension is then placed on the spinal ligaments to maintain proper mechanical support. The ligaments may calcify in a process that some researchers believe is an adaption to allow greater load bearing. Increased BMI is associated with greater frequency of osteophyte formation at both the dorsal and lumbar spine.[15] Osteophytes are common in ankylosing spondylitis, a spinal condition which has a high inflammatory element. Osteophytes also tend to have a higher incidence in persons with high BMI.

Perioperative Complications

General surgery carries risks for any individuals, but obese individuals are at particular risk. Morbidly obese patients are at risk in any form of anesthesia associated with invasive surgery. Also, diabetes, very common in obesity, may significantly slow wound healing. The effect of obesity on the outcome of spinal surgery specifically is not certain. Many studies show a clear increase of pneumonia, deep vein thrombosis and wound infection. However, some studies show no such association and some even show a better outcome in overweight individuals.

The obesity epidemic undoubtedly has affected the spinal health of the American population. The rapid onset of this epidemic has left health care providers and researchers scrambling to determine the causes of this increase and develop treatments. Lifestyle change, pharmacological intervention and surgical intervention all have a high relapse rate. Further research is required to understand the psychological, biochemical and societal factors which affect appetite and obesity. The current issue has brought together researchers and clinicians with different perspectives on this topic to elucidate the problem and suggest solutions.

Anne G. Copay, Ph.D.

Dr. Copay studies the outcomes of surgical and non-surgical spine treatments. She published several articles on the outcomes of spine fusion. She has on-going research projects concerning the effectiveness of new spine technologies and the long-term outcomes of surgical treatments.

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Body Mass Index and Body Fat

William J. Kemp, III

The Body Mass Index (BMI) was devised by a Belgian mathematician, Adolphe Quetelet, in the mid-nineteenth century. BMI is based on the principle that body weight is proportional to the squared height in adults.[1] The use of BMI for the classification of weight status is based on epidemiological studies. The classifications of "normal weight", "overweight" and "obese" are linked to risks of morbidity (hypertension, diabetes, dyslipidemia) and overall mortality.[2] Furthermore, BMI cut-points are consistent with the guidelines of the World Health Organization and provide a systematic way to evaluate the worldwide obesity epidemic.

While high BMI is associated with obesity-related morbidity, it is excess body fat that is responsible for the morbidity of obesity. Typically, body fat percentages of 12-16% for men and 20-25% for women are considered healthy. Several recommendations for body fat have been suggested, as shown in Table 1. BMI does not accurately measure body fat. Increased body weight will result in a higher BMI, whether the added weight is due to fat or lean tissue. An increase in body weight is likely due to increased fat in average individuals, but to an athlete it may be due increased muscle mass. Hence, a high BMI may not carry a higher morbidity risk for individuals with low body fat.[3] The imperfect relationship between body fat and BMI might be the reason why individuals with cardiovascular disease have a better chance of survival if they have an overweight BMI than a normal weight BMI.[4] In order to evaluate the proportions of fat and lean tissues, it is necessary to measure body composition. The various methods of measuring body composition vary in accuracy and practicality.

Table 1. Body Fat Percentages (The American Council on Exercise)

Description	Women	Men
Essential fat	10-12%	2-4%
Athlete	14-20%	6-13%
Fitness	21-24%	14-17%
Acceptable	25-31%	18-25%
Overweight	32-41%	26-37%
Obese	42%+	38%+

Underweight / Healthy / Overweight / Obese / Extremely obese

WEIGHT lbs	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215
kgs	45.5	47.7	50.0	52.3	54.5	56.8	59.1	61.4	63.6	65.9	68.2	70.5	72.7	75.0	77.3	79.5	81.8	84.1	86.4	88.6	90.9	93.2	95.5	97.7
HEIGHT in/cm																								
5'0" - 152.4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
5'1" - 154.9	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	36	37	38	39	40
5'2" - 157.4	18	19	20	21	22	22	23	24	25	26	27	28	29	30	31	32	33	33	34	35	36	37	38	39
5'3" - 160.0	17	18	19	20	21	22	23	24	24	25	26	27	28	29	30	31	32	32	33	34	35	36	37	38
5'4" - 162.5	17	18	18	19	20	21	22	23	24	24	25	26	27	28	29	30	31	31	32	33	34	35	36	37
5'5" - 165.1	16	17	18	19	20	20	21	22	23	24	25	25	26	27	28	29	30	30	31	32	33	34	35	35
5'6" - 167.6	16	17	17	18	19	20	21	21	22	23	24	25	25	26	27	28	29	29	30	31	32	33	34	34
5'7" - 170.1	15	16	17	18	18	19	20	21	22	22	23	24	25	25	26	27	28	29	29	30	31	32	33	33
5'8" - 172.7	15	16	16	17	18	19	19	20	21	22	22	23	24	25	25	26	27	28	28	29	30	31	32	32
5'9" - 175.2	14	15	16	17	17	18	19	20	20	21	22	22	23	24	25	25	26	27	28	28	29	30	31	31
5'10" - 177.8	14	15	15	16	17	18	18	19	20	20	21	22	23	23	24	25	25	26	27	28	28	29	30	30
5'11" - 180.3	14	14	15	16	16	17	18	18	19	20	21	21	22	23	23	24	25	25	26	27	28	28	29	30
6'0" - 182.8	13	14	14	15	16	17	17	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27	28	29
6'1" - 185.4	13	13	14	15	15	16	17	17	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27	28
6'2" - 187.9	12	13	14	14	15	16	16	17	18	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27
6'3" - 190.5	12	13	13	14	15	15	16	16	17	18	18	19	20	20	21	21	22	23	23	24	25	25	26	26
6'4" - 193.0	12	12	13	14	14	15	15	16	17	17	18	18	19	20	20	21	22	22	23	23	24	25	25	26

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Under-water weighing is considered the gold standard for determining body composition. According to the physics principles of buoyancy, lean tissue is denser than water and fat tissue is less dense than water. Therefore, an individual with more body fat will be lighter under water due to the greater buoyancy of his or her fat tissue.[5] Under-water weighing requires cumbersome equipment and is confined to research institutions.

- Dual Energy X-ray Absorbtiometry (DXA) was originally developed to measure bone density and is now able to measure fatty tissue, lean tissue, and bone. DXA generates x-rays at two different energies where the differential attenuation between the two is used to measure bone mass and soft-tissue mass.[6] DXA is becoming the new gold standard of body composition but relies on expensive equipment.

- Bioelectrical Impedance Analysis (BIA) measures the ability of the body to conduct an electrical current. The electrical impedance indirectly indicates the amount of lean tissue since lean tissue is more electrically conductive due to its higher water content. Traditionally, BIA required that electrodes be attached to the wrist and ankle, but pressure-contact electrodes have recently been introduced, such as in household bathroom scales.[7] However, bathroom scales do not provide accurate individual body fat measurement.[8]

- Skin fold measurements involve using a caliper to measure the thickness of the fat depot under the skin in different areas of the body. The accuracy of skin fold measurements depends on the skills and experience of the technician.

- Air displacement measurement requires placing a patient in a closed chamber to measure the volume of air displaced and calculate body density. The denser (i.e. leaner) a person is, the smaller the amount of air displaced.[9]

Thus, body composition is a more reliable indicator of obesity and cardiovascular risk than BMI. Despite its shortcoming, BMI is a practical and useful indicator of health risks. A BMI over 30 kg/m^2 carries a greater risk of morbidity for the non-athletes amongst us. A BMI in the healthy range will not carry an elevated health risk only if it is coupled with a healthy body fat content.

William J. Kemp, III

William Kemp was awarded the SRF 2009 Medical Research Sciences Award. This prestigious award is presented annually to a pre-medical or medical student with high educational goals. He will graduate from Notre Dame University in May 2010. He was president of the Medical Explorers Program at Notre Dame University and performed research in Molecular Cell Biology.

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Anesthetic Risks Associated with Obesity

Michael Bradish, M. D.

Patient obesity presents a particular challenge for anesthesiologists during complex procedures, such as spinal surgery. Over the past few decades, the challenge has only increased as the prevalence of obesity in America has continued to grow to near epidemic proportions. Recent Center for Disease Control studies estimates that nearly 34%, (72 million people), of the American adult population is obese.[1] The list of health implications associated with obesity is long, and high on the list is the obese patient's increased risk for surgical and anesthetic complications. These complications can occur pre-operatively, intra-operatively and post-operatively. By identifying and monitoring these potential complications, practitioners can help mitigate, although not eliminate, the risks associated with patient obesity.

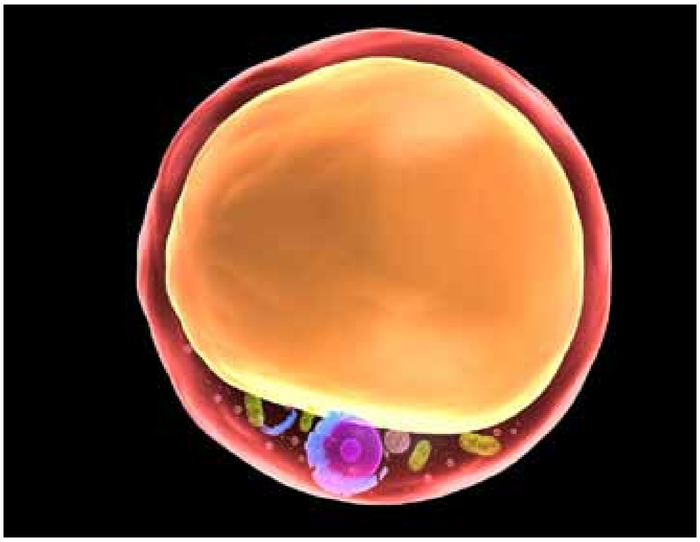
Introduction

The increase of the obesity epidemic over the last few decades has been accompanied by an increase in the incidence of obesity-related surgical complications. These factors may present potential complications pre-operatively, intra-operatively, and post-operatively and include respiratory, cardiovascular and gastrointestinal complications, airway considerations and positioning considerations.

Respiratory System

Respiratory complications are among the most common problems encountered when obese persons undergo surgery. Excess weight means patients need to consume more oxygen to support their excess body tissues. The increased oxygen demand and metabolism in turn increases carbon dioxide production. As a result, the obese patient has a higher breathing requirement per minute. Respiratory mechanics and efficiency are also affected; fat deposits in the abdomen and chest wall increase the work load on the lungs and lead to difficulty in breathing. This labored breathing further increases the metabolic demands on the patient's system and can lead to complications both during induction of anesthesia and afterwards.

Photo courtesy of ECRI Institute



Fat Cell

Because body fat alters the movement of the chest wall and diaphragm and decreases lung volumes, it has the potential to mimic restrictive lung disease. The volume of air present in the lungs at the end of passive expiration, known as Functional Residual Capacity (FRC), is markedly lower in patients with high BMI. When the patient assumes the supine position usually

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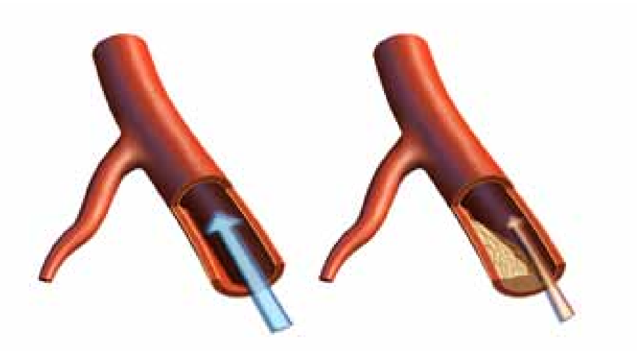


Example of a normal blood vessel (Left) and a clogged artery (Right)

required in the operative setting, the effect is even greater than normal.[2] This smaller than normal reserve of oxygen can translate into rapid and severe drops in blood oxygenation during the induction anesthesia.[3] If unchecked, poor arterial oxygenation can lead to cardiac arrhythmias, brain damage, diffuse tissue damage, or even death. Special efforts to administer high concentrations of oxygen by the anesthesiologist immediately, pre-induction, can help lessen the chances of these problems.

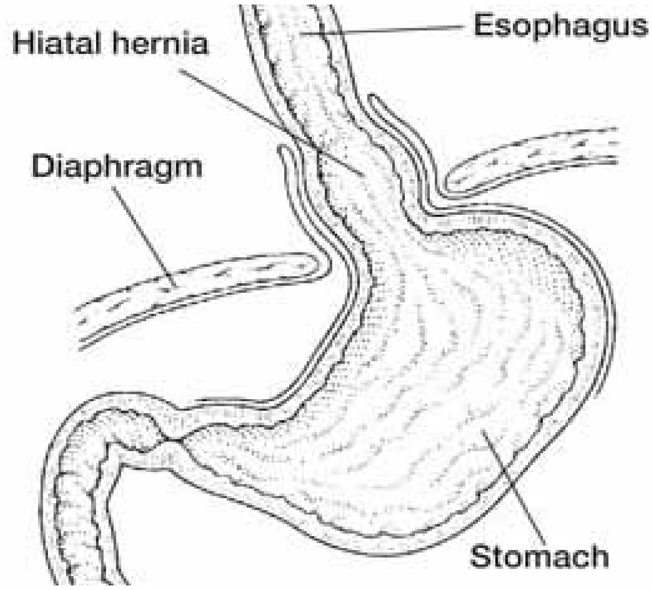
In the peri-operative period, obese patients have elevated risks for atelectasis, or collapse of normally expanded lung tissue, and pneumonia. Atelectasis occurs when the closing capacity (CC), the lung volume at which the smallest branches of the lung begin to collapse, falls below the FRC. During atelectasis, the patient's lungs may fail to adequately oxygenate the blood and lead to significant oxygen desaturation. Post-operatively, the patient continues to be at increased risk for lung collapse, which can lead to low blood oxygen content, and even pneumonia. Hypoxemia in turn can lead to poor wound healing and post operative wound infections. Deep breathing exercises and early ambulation after surgery can help to lessen the chances of atelectasis.

Cardiovascular System

Excess weight places a proportionately higher work load on the obese patient's heart. For this reason, obesity is closely associated with arterial hypertension.[4] The obese patient's heart must pump an extra 0.1 liter of blood per minute for each additional kilogram over his or her ideal body weight.[5] One way for the heart to compensate is by increasing the volume of blood pumped with each heart beat. Over time, physical changes in the heart will result and can include enlarged size, arrhythmias, heart valve issues, and ischemic changes. For instance, obese patients are well known to have twice the risk of coronary artery disease that normal weight patients have. A careful preoperative evaluation by a cardiologist can help to ascertain whether coronary artery disease exists and whether a cardiac intervention is needed. Additionally, preoperative medical treatment of hypertension can help decrease the risks of heart attack and stroke.

Gastrointestinal System

Obesity is also associated with a significantly higher incidence of hiatal hernias and gastroesophageal reflux disease. These underlying conditions, together with increased intra-abdominal pressure from the adipose tissue surrounding the abdomen, place the obese patient at higher than normal risk for peri-operative aspiration, the inhalation of the stomach contents into the lungs. Bacterial pneumonia and pneumonitis from aspiration can have severe outcomes, including death.



Example of Hiatal Hernia Courtesy of NDDIC

While they cannot eliminate all additional risks associated with underlying gastrointestinal disorders, special anesthetic techniques, including rapid sequence induction of anesthesia (RSI) and preoperative antacids, can help lessen these risks.

Airway Considerations

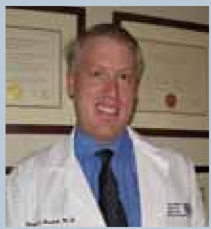
General anesthesia for spine surgery usually requires use of an endotracheal breathing tube placed during the induction of anesthesia. Obesity can make the traditional means of placing this tube very challenging. Obstructive sleep apnea, associated with obesity, may make hand ventilation of the patient difficult. Additionally, fatty redundant tissues in the posterior mouth, poor neck mobility and large neck circumference may make the placement of the breathing tube extremely difficult. Because it may take longer to place the breathing tube in the obese patient, rapid blood desaturation may result. This problem is compounded by the obese patient's already limited oxygen reserves and increased oxygen consumption. As a result, it may be necessary to place the breathing tube in obese patients while they are awake, using an alternate technique like awake fiberoptic intubation that, although less comfortable for the patient, reduces the risk of desaturation or failed attempts at intubation.

Positioning Considerations

The obese patient must also be carefully positioned during surgery. Pressure ulcers and deep venous thromboses (DVTs) are all more common in this patient group. Even with meticulous planning and positioning, nerve injuries including brachial plexus injuries, remain much more common among obese patients. Prone positioning for spine surgery only increases this possibility. The use of compression stockings during and after surgery helps mitigate these risks.

Conclusion

Despite the dire sounding list of risks and potential complications faced by obese patients undergoing major surgery, it must be emphasized that most do undergo even complex procedures like spinal surgery without complication. Careful study of the risks associated with obesity has allowed practioners to modify their procedures to decrease some of the heightened peri-operative risk for these patients to more normal levels. With vigilance and anticipation of the particular problems faced by the obese patient, practitioners can greatly improve surgical outcomes in this patient group.



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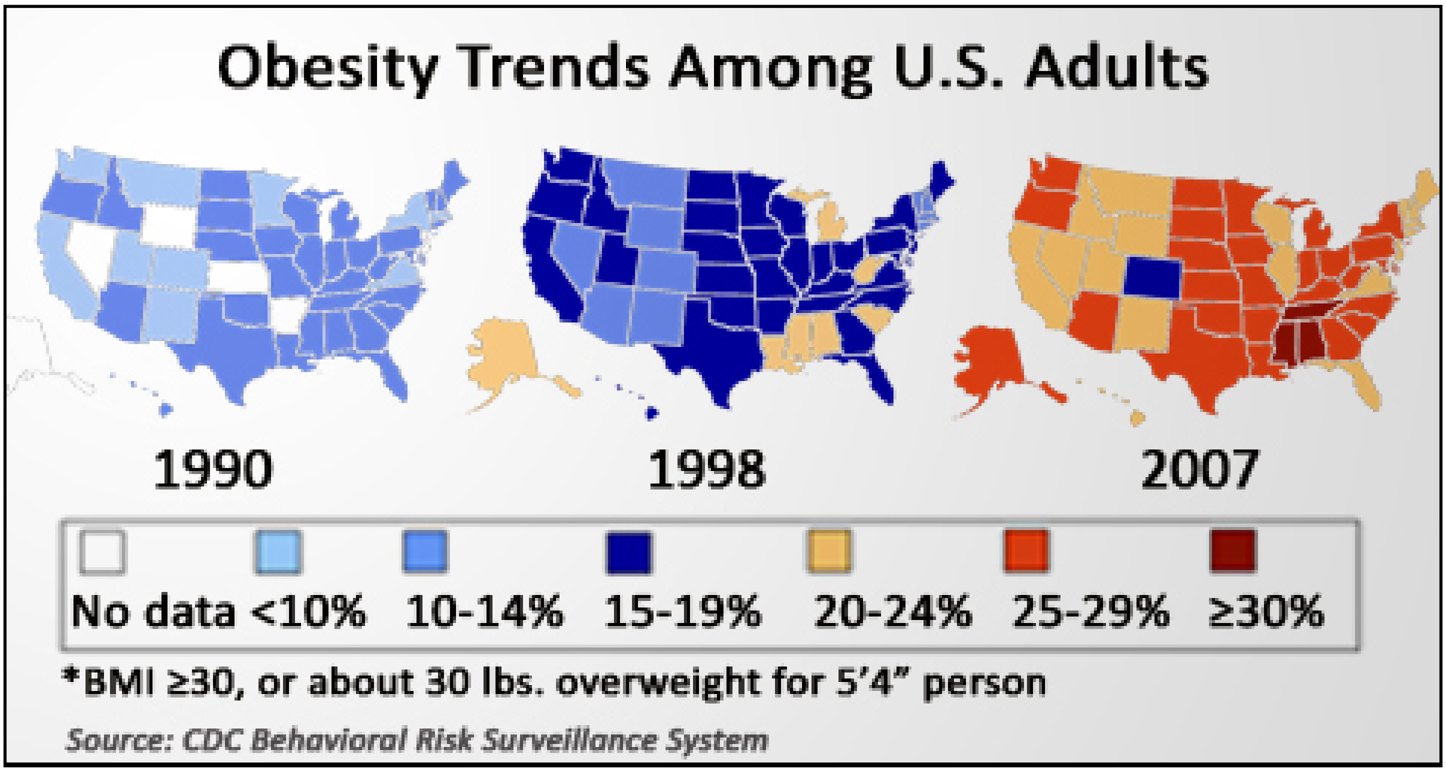
Lumbar Fusion and Obesity

Leah Carreon, M. D.

Obesity has been associated with back problems, and spinal surgeons find that surgery on obese patients is more challenging. The evidence regarding the complication rate and the outcomes of spinal surgery in obese versus non-obese patients is mixed. This article provides a short overview of the issues surrounding the performance of spinal surgery on obese patients.

Obesity has reached epidemic proportions in the United States with recent statistics showing that 67% of the U.S. population is now overweight and 32% is obese.[1,2] Obesity has long been associated with a multitude of health problems and has been shown to be an independent risk factor for low back pain and disability from pain.[3-6] Obese individuals have been found to be at an increased risk for lumbar disc degeneration with the risk increasing 4 times when the individual is overweight at a young age.[7]

Vogt and colleagues reviewed the prevalence and risk factors in postmenopausal women who had back pain, and found that postmenopausal women who had low back pain had a higher BMI and weighed approximately 2 to 3 kg more than those who did not have back pain.[5] This may be due to changes in posture and in the biomechanics of the hip joint especially during standing tasks involving trunk forward flexion.[8,9] This may also explain why obese individuals are at a higher risk of transitioning from acute to chronic back pain in an occupational setting.[10] With all these studies, it is not surprising that some degree of bias probably exists among spinal surgeons against operating on obese patients. Surgeons generally perceive that operative times are longer, exposure of the spine is more challenging, and other technical aspects of the surgery are more difficult in obese compared to normal weight patients. Patient positioning for people undergoing back surgery is usually done with the patient prone over a frame. In order to minimize blood loss, the abdomen has to be completely free, which is difficult in obese patients. Some studies have reported higher blood loss in obese patients undergoing spine surgery, while others have



not.[11-12,13-15,16-18] Despite concerns about technical difficulties, the operative time in obese patients was similar to those in normal weight patients.[18]

The strong association of back pain, postural and biomechanical alterations with obesity adds uncertainty regarding the source of a patient's symptoms, even in the presence of otherwise acceptable surgical indications. For this reason, some surgeons may expect inferior clinical results in obese patients undergoing spinal surgery.[3-6,8-10]

Obese patients with low back complaints presenting at clinic have worse functional and health-related quality of life scores.[19,20] However, several studies have shown that when surgeons perform surgery on obese patients, the degree of clinical success is similar to patients who are not obese.[13,14,16,19,21,22] In 32 obese patients who had minimally invasive discectomy, 97% reported being satisfied with the results of surgery.[23] In patients who underwent posterolateral instrumented fusion for degenerative low back conditions, improvements in SF-36 PCS, ODI, back and leg pain numeric scores were similar in obese and non-obese patients.[19] In adolescents undergoing correction for scoliosis, there was no difference in the degree or maintenance of curve correction and in clinical outcomes between patients who were obese and those who were normal weight.[18] However, in 367 elderly patients who had decompressive surgery without fusion, Gepstein showed that a higher percentage of very dissatisfied patients were obese.[21] Interestingly, Vaidya has shown no significant weight loss in obese patients after undergoing low back surgery, despite improvements in back and leg pain and functional outcomes.[14]

The relationship between obesity and the rate of complications after spine surgery is still not well-defined. Some authors have reported no correlation between the degree or presence of obesity and complications.[13,18] Whereas, other authors have reported a correlation between obesity and the occurrence of complications with reported incidence rates ranging from 37% to 50%.[19,21,22,24-26] The complication that has been more consistently reported to be higher in obese compared to normal weight patients is surgical site wound infection.[14,19,27,28]

Obese individuals are at higher risk for low back pain and disability. In the presence of definite indications

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for spine surgery, functional improvements can be expected, but the rate of complications, especially wound infection, is higher.

Leah Carreon, M.D.

Dr. Carreon is the Clinical Research Director at the Kenton D. Leatherman Spine Center. She studies the effectiveness of spine treatments and is the author of numerous articles concerning technological advances in spine treatment as well as the assessment of the outcomes of spine surgery.

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Impact of Obesity Surgery on Bone Health

Amy P. Powell, M.D.

The prevalence of obesity has increased dramatically in the United States over the last decade. One option in the treatment of this condition is through bariatric surgery which may be either a restrictive procedure such as Laproscopic Adjustable Gastric Banding or malabsorptive methods such as Roux-en-Y gastric Bypass. The following examines the types of bariatric surgery, the implications of these surgeries, and their effects on bone density and bone health.

Introduction

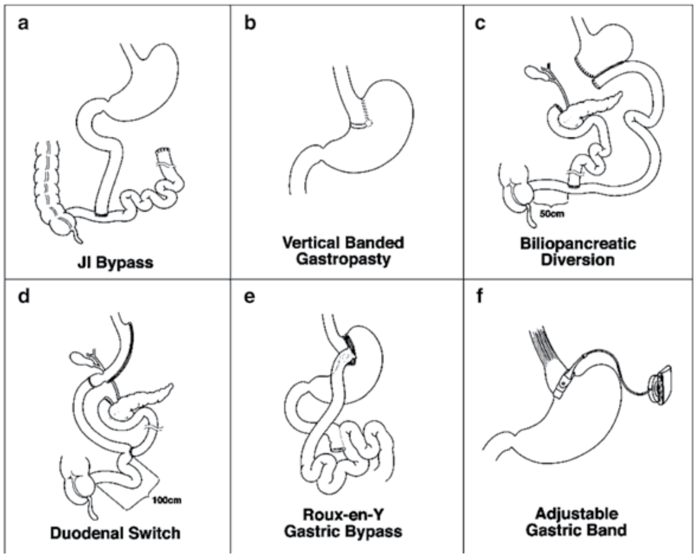
Obesity is a chronic disease that is increasing in prevalence and reaching epidemic proportions in the United States. The obesity rate increased 50 percent in women from 1991-1998 and doubled in men in the same time frame. Fortunately obesity rates appear to have stabilized recently, though in 2009 twenty-three states again reported an increase in overweight and obese adults.[1,2]

Obesity is defined as body mass index greater than 30 kg/m^2. Body mass index is calculated by dividing a person's body weight in kilograms by the height in meters squared. Normal BMI is less than 25 kg/m^2. A BMI between 25 and 29.9 is considered overweight. More than a third of adults in the United States are obese (over 70 million people), and almost two-thirds are overweight.

Morbid obesity, defined as 100 pounds or more overweight, affects almost 15 million Americans. Obesity has been correlated with coronary artery disease, diabetes mellitus, hyperlipidemia, hypertension, degenerative joint disease and obstructive sleep apnea, among other medical problems. It is known that weight loss is successful in treating obesity-related medical problems. While diet and exercise are always recommended as the first line treatment of obesity for those who are extremely overweight, diet and exercise alone may not be enough.

The popularity of obesity surgery has risen in recent years. 1.2 million Americans have had an obesity procedure in the past decade. From 1996-2002, bariatric surgical procedures increased sevenfold and tripled in those under the age of 20 in the same time frame.[3] Studies have shown that bariatric surgical procedures are helpful in treating obesity. A mean overall percentage of excess weight loss of 61 percent was demonstrated in one study.[4] In a Swedish study, patients who underwent weight loss surgery were less likely to require medications for diabetes and heart disease, had a lower medication cost overall, and had better chance of recovering from diabetes, hypertension, and hypertriglyceridemia. The group undergoing bariatric surgery had a 29 percent reduction in mortality rate.[5]

Nutritional and metabolic derangements are known to occur with Roux-en-Y gastric bypass surgery, one of the most common surgical procedures performed to treat morbid obesity. Vitamin deficiencies resulting from surgical treatment may impact bone health long term.



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Types of Bariatric Surgery

There are two main categories of obesity surgery: restrictive and malabsorptive. Restrictive

Image of a LAP-BAND Laproscopic Adjustable Gastric Band. Courtesy of Allergan.

procedures limit caloric intake by reducing the size of the stomach reservoir. The most common application of this technique is laparoscopic adjustable gastric banding (LAGB). Pure malabsorptive procedures are not typically offered in the United States, but Roux-en-Y gastric bypass (RYGB) offers components of both restrictive and malabsorptive calorie restriction. RYGB is the most commonly performed bariatric surgery in the United States and is considered the gold standard procedure.

Laparoscopic Adjustable Gastric Banding

LAGB is performed in the United States using two very similar implants: LapBand™ and Realize™. Both bands are made of a soft silicone ring connected to an infusion port through which saline can be injected. As fluid enters the band, resistance increases. The surgeon may adjust the resistance of the band. This technique has become popular due to simplicity and lower complication rates than more involved procedures such as Roux-en-Y gastric bypass surgery. It is adjustable and reversible, so if, for example, a woman with a band becomes pregnant, the band may be adjusted or removed to allow for greater caloric intake during pregnancy.

LAGB has provided mixed results in early American studies, but long-term follow up is available from Australia and European countries, which have been using gastric banding for treatment of morbid obesity for a longer duration (LapBand ™ was approved for use in the US in 2001). Studies have shown mean excess weight loss of 45 to 75 percent at two years, along with improvements in quality of life, diabetes, hypertension and sleep apnea. [6-15] Most surgeons counsel patients on the fact that weight loss resulting from LAGB may be slower and slightly less than with Roux-en-Y gastric bypass. Nonetheless, as a truly restrictive procedure, nutritional deficiencies are less of an issue as normal absorption through the proximal small bowel is preserved.

Roux-en-Y Gastric Bypass

Roux-en-Y gastric bypass (RYGB) evolved in the 1960s after observations that patients undergoing partial gastrectomy had significant, sustained weight loss post-operatively.[16] It is mainly a restrictive operation, but a component of malabsorption contributes to weight loss. It is thought to be superior to purely restrictive procedures (LAGB) in long-term weight loss.

During the RYGB, surgeons divide the stomach to create a small pouch in the stomach which connects directly to the middle of the small intestine through a tight band. The majority of the stomach and the first part of the small intestine (the duodenum) are bypassed, resulting in fewer calories being absorbed. The small intestine fragment (Roux limb) is then attached onto a lower part of the small intestine, allowing for delivery of nutrients from the stomach remnant, liver and pancreas to join the absorbed food. Digestion of food occurs in the common channel where the stomach pouch and Roux fragment meet the lower part of the small intestine. Weight loss occurs in a restrictive fashion- the small pouch (which holds approximately one cup), and tight outlet result in fewer calories consumed and the patient experiences an early sense of satiety. Weight loss also occurs due to malabsorption, as food bypasses the sites where many nutrients (and calories) are absorbed.

The degree of malabsorption is related to the length of the Roux segment. It appears that the longer the limb segment, the greater degree of weight loss, but lengthening the Roux segment shortens the segment where nutrient absorption occurs, leading to an increased risk of vitamin deficiencies. The optimal length of the Roux segment to optimize weight loss and minimize malabsorption is controversial.[17]

Calcium Absorption and Malabsorption

Nutrients pass from the mouth into the stomach are broken down there and then pass into the proximal small intestine. The first part of the small intestine, the duodenu absorbs approximately 80 percent of calcium in food. The remaining 20 percent of calcium is poorly absorbed in the distal small intestine.

In RYGB, the part of the small bowel responsible for absorbing the majority of calcium from food intake is bypassed. The remaining 20 percent of calcium is absorbed in the distal small bowel, but is absorbed in a fashion dependent on vitamin D. RYGB may also compromise absorption of vitamin D due to poor mixing of fat and bile salts in the common channel resulting in a decrease in fat absorption, as vitamin D is a fat soluble vitamin. Additionally, increased fat in the stool, known as steatorrhea, further reduces calcium absorption. It is clear that in RYGB, there are multiple mechanisms leading to calcium and vitamin D malabsorption. In LAGB, there is decreased overall caloric intake, but nutrient absorption in the early small bowel remains intact.

The decrease in calcium absorption in RYGB seems to result in upregulation of parathyroid hormone (PTH), a vital hormone for regulating calcium levels in the body. When the body senses suboptimal calcium absorption, PTH increases calcium resorption from bone. Hypocalcemia also stimulates conversion of inactive vitamin D (25-hydroxy vitamin D) to its more active metabolite (1,25 dihydroxy vitamin D), again resulting in increased calcium resorption from bone.[18]

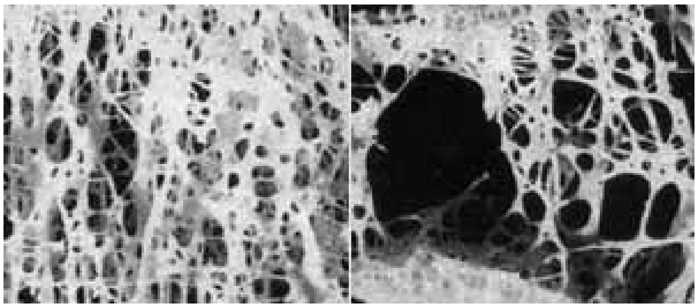


Image of Normal bone (left) and Osteoporotic Bone (right) Courtesy of IOF.

Image of a person recieving a DXA, or Dual energy X-ray absorptiometry scan . This is a machine that measures bone mineral density by using 2 different X-ray beams at different energy levels.

Studies on Bone in Gastric Bypass Patients

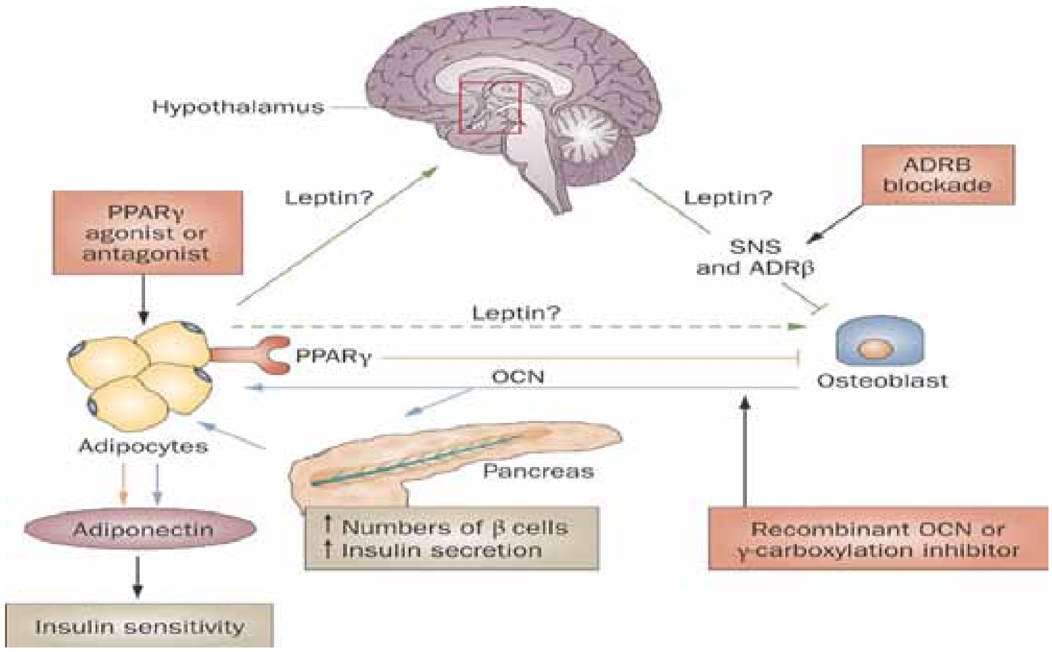
Studies in patients after RYGB have shown increases in bone resorption. Coates et. al. found increases in markers of bone turnover and decreases in bone mineral density measured by DXA within 3-6 months after surgery.[19] Additionally, hyperparathyroidism and vitamin D deficiency have been shown to be worse in the first post-operative year, but may progress over time and lead to osteopenia, osteoporosis, and osteomalacia if untreated. [20-21] Because the spine consists of mainly trabecular bone, which is more metabolically active, it may be more prone to humoral factors resulting from RGYB.

The mechanism of bone loss after RYGB is complex, and multiple interrelated issues likely contribute. Obesity is generally considered protective of osteoporosis, and rapid weight loss is known to produce bone loss. Decreased mechanical loading of the bone contributes. Other hormones may also play a role- there is recent interest in adiponectin, a hormone known to negatively correlate with bone mineral density in humans. One study has recently shown a substantial increase in adiponectin levels after RYGB, which seems independent of other variables.[22] These same authors reported that the combination of initial weight, weight loss, fat mass loss, and adiponectin levels only explain 37% of the BMD decrease in their study population, and the authors postulate that the poor absorption of calcium and vitamin D may be a large contributor to the loss of bone mass in the first year after RYGB.

One study recently presented at the annual meeting of The Endocrine Society made national headlines. Haglind et. al. reported that a population of bariatric surgery patients was more likely than an age- and sex-matched population to experience a fracture, particularly at the hand and foot.[23] The authors separated the study population into groups by Roux limb length (100-150 cm, 150-300 cm, and greater than 300 cm). This study in the future may provide guidance as to optimal Roux limb length to allow for weight loss while minimizing negative metabolic effects. At this time, most surgeons perform RYGB with limb lengths less than 100 cm. This was a preliminaryreport published in abstract form, and more information will come as this group of authors continues to collect information from their study population.

Treatment recommendations

The amount of calcium and vitamin D to recommend after RYGB remains unclear. Goode et. al. reported that diminished vitamin D levels and hyperparathyroidism seen post-operatively could not be corrected with administration of calcium 1200 mg and vitamin D 800 IU daily.[24] Some bariatric surgeons



The 3 distinct networks that link Bone and Fat

Leptin signaling via the hypothalamus to the SNS and ADRB2 on osteoblasts triggers bone loss, but putative direct anabolic effects of leptin on osteoblasts remain unresolved. OCN produced by osteoblasts decreases fat mass, promotes adiponectin production and insulin sensitivity, and increases numbers of pancreatic -cells and increases insulin secretion. Adipose-derived PPAR 2 promotes bone marrow adiposity by inducing adiponectin production and decreases bone mass. Potential therapeutic targets include ADRB2 blockade to reduce leptin-induced bone loss, recombinant leptin or leptin mimetic to increase bone mass, PPAR agonism or antagonism to inhibit bone marrow adiposity and increase osteoblast differentiation, and recombinant OCN or -carboxylation inhibitors to inhibit adipose deposition and improve bone mass. Leptin, OCN and PPAR 2 signaling pathways are shown in green, blue and orange, respectively; therapeutic targets are shown in red boxes. Abbreviations: ADRB, -adrenergic receptor; OCN, osteocalcin; PPAR , peroxisome proliferator activated receptor gamma; SNS, sympathetic nervous system Reprinted with permission from Macmillan Publishers Ltd: *Nature Reviews Rheumatology* 5, 365-372 (July 2009) Masanobu Kawai, Maureen J. Devlin & Clifford J. Rosen doi:10.1038/nrrheum.2009.102

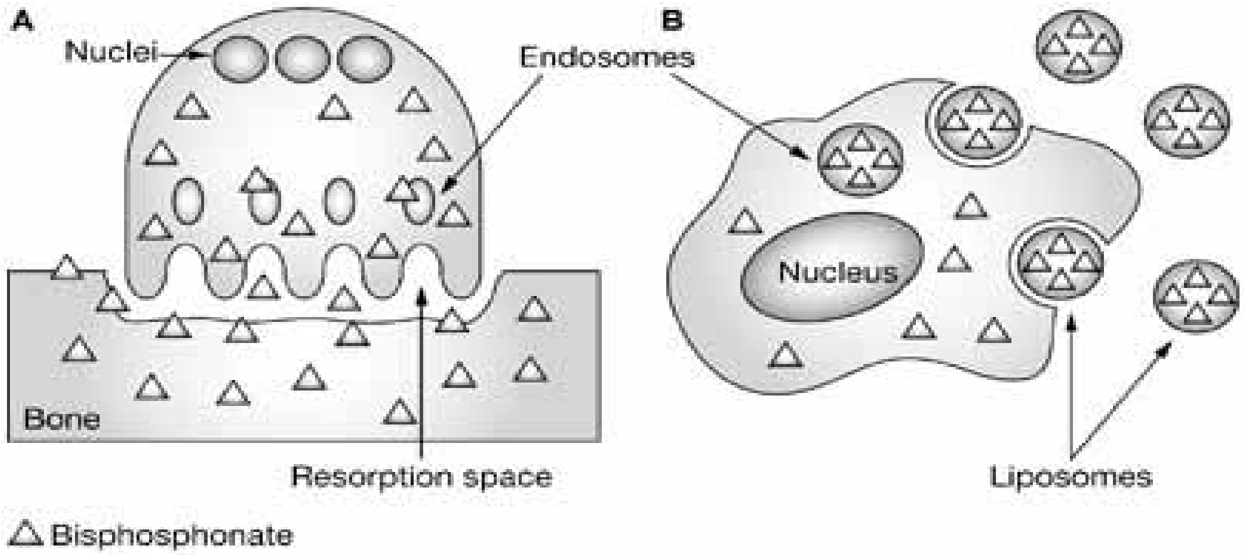


Figure 2. Models for bisphosphonate targeting of (A) osteoclasts and (B) macrophages.

Bisphosphonates (triangles) target osteoclasts by binding to bone mineral. Osteoclasts release bound bisphosphonate by acidification of the small sealed resorption space and endocytose bisphosphonate along with dissolved salts and matrix fragments. Alternatively, if bisphosphonates are administered in liposomes, they are targeted to macrophages, which phagocytose these structures. In both cases, high intracellular exposure to bisphosphonates occurs, allowing expression of cytotoxic activity. Reprinted by permission from Macmillian Publishers Ltd:*Nature Clinical Practice Oncology* (2007) 4, 42-55 soi:10.1038/ncponco688

are recommending supratherapeutic doses of both calcium and vitamin D to their patients. This may be warranted and deserves further investigation.

It is recommended that all postmenopausal women with risk factors for fracture undergo bone densitometry screening. This should include gastric bypass patients. While appropriate calcium and vitamin D recommendations cannot at this point be determined, all RYGB patients should be encouraged to take at least calcium 1200 mg and vitamin D 800 IU daily. Carrasco et al reported that the patients in their study group approached 83 percent of this recommendation, and there was no significant change pre- and post-surgery.[22] Patients must be counseled to aggressively attempt to meet these goals.

Current evidence suggests that 25 hydroxy vitamin D serum levels greater than 50 nmol/l (20 ng/ml) are necessary to support bone health, requiring vitamin D intake greater than 20 mcg daily. The current recommended daily allowance is 400-800 IU daily, though there is little risk for toxicity with higher supplementation levels. Our practice in both a general osteoporosis population and a bariatric surgery population is to evaluate 25 hydroxy vitamin D levels regularly, and supplement to the above referenced therapeutic range. Our experience has been that it takes longer to achieve optimal levels in patients who have undergone RYGB.

For those gastric bypass patients with osteoporosis and high risk for fracture, the bisphosphonate class of medications is reasonable to consider. Bisphosphonates are antiresorptive medications that slow the bone turnover seen with RYGB. Suzuki et. al. found improvement of bone turnover markers and bone mineral density with alendronate and vitamin D3 in a population of gastrectomy and gastric bypass patients.

Conclusions

Bariatric surgery results in profound weight loss, which leads to decreases in bone mineral density by reducing mechanical loading of the skeleton. In those procedures that have a malabsorptive component, such

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as gastric bypass surgery, other negative metabolic consequences may occur. It is important for patients and physicians to be aware of the impact bariatric surgery may have on bone health. Further studies are needed to clarify the mechanisms by which bariatric surgery leads to decreases in bone mineral density. Preliminary data suggest an increased fracture risk in patients after bariatric surgery, and more research is necessary.

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Dr. Powell is a board certified Sports Medicine physician serving as a team physician for the Univeristy of Utah. She specializes in the care of active people and athletes of all ages. Dr. Powell's clinical interests include non-surgical management of musculoskeletal problems afflicting active people across the lifespan. She has specific clinical interests in prevention and management of injuries in the female athlete, metabolic bone disease and non-surgical management of osteoarthritis in active patients.

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Understanding the Causes and Consequences of Overweight and Obesity

Casey P. Durand, M.P.H. and Genevieve F. Dunton, Ph.D., M.P.H.

Rates of overweight and obesity have risen dramatically in the United States across recent decades. These conditions pose a serious concern to public health by increasing risks of heart disease, metabolic disorders, stroke, cancer, orthopedic morbidity, and other chronic diseases. Thus, there is an urgent need to identify modifiable risk factors and develop programs and policies to reduce and prevent overweight and obesity in children and adults. To this end, the goal of this review is to describe the magnitude of the problem and current research involved in understanding the causes of overweight and obesity, particularly focusing on psychosocial and environmental influences and potential new directions for research that will help us better inform future public health interventions.

Epidemiology

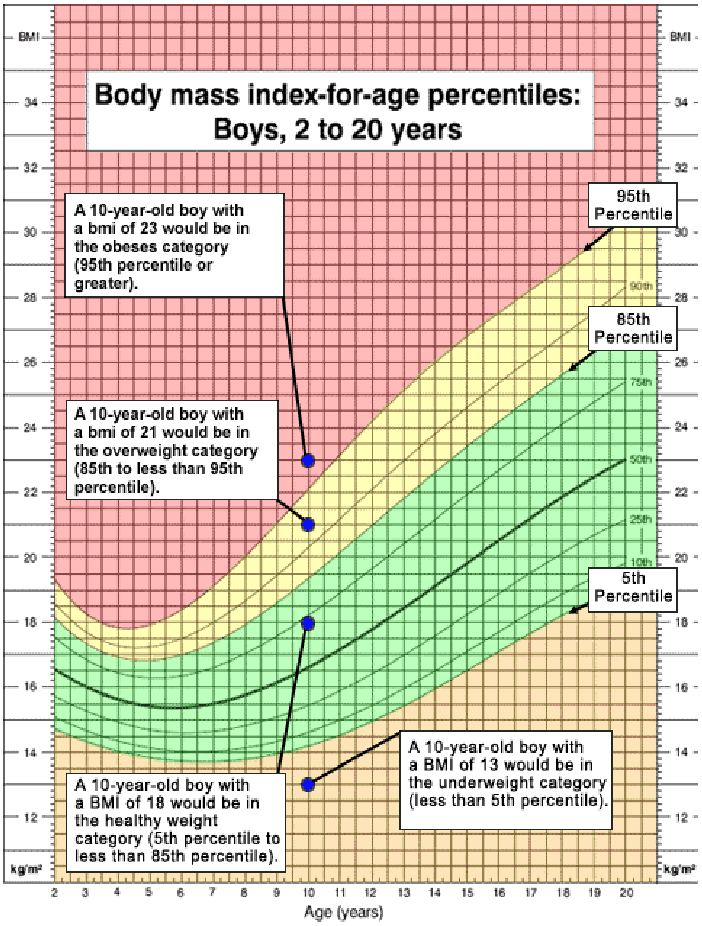
Overweight and obesity are based on an individual's body mass index, commonly called BMI, a number that is derived from measurements of height and weight and calculated as weight (kilograms)/ height (meters) squared.[1] The Centers for Disease Control and Prevention define overweight for adults as someone who has a BMI between 25 and 29.9, and obesity as a BMI of 30 or higher.[1]

BMI	Weight Status
Below 18.5	Underweight
18.5 – 24.9	Normal
25.0 – 29.9	Overweight
30.0 and Above	Obese

For children, these categories are based on age- and sex-specific growth charts which account for the unique ways in which their bodies develop during childhood. Overweight is at or above the 85th percentile and less than the 95th percentile on the appropriate growth chart, while obesity is at or above the 95th percentile.[1]

According to the 2005-06 National Health and Nutrition Examination Survey (NHANES), approximately 33% of adults are overweight, 34% are obese and 6% are extremely obese.[2] The latter two categories have increased significantly over the past two decades. The 1988-94 NHANES reported the prevalence of obesity and extreme obesity as 23% and 3%, respectively.[2] Likewise, the 2005-2006 NHANES found that among children between the ages of 2 and 19, approximately 30% were at or above the 85th percentile (overweight), 16% were at or above the 95th percentile (obese), and 11% were at or above the 97th percentile (extremely obese).[3] As with adults, children have increased markedly in weight over the years. The 1988-94 NHANES showed that only 14% of children between the ages of 6 and 17 were overweight and 11% were obese.[4] These statistics are particularly alarming because children who are overweight are significantly more likely to be overweight as adults.[5]

Overweight and obesity exhibit disparities across racial/ethnic groups and socioeconomic levels. Among adult females age 20 and older, approximately 51% of blacks and 40% of Hispanics, as compared to 31% of whites, are obese. Men show a more even distribution, with obesity rates of 29% for whites, 30% for blacks, and 29% for Hispanics.[6] Disparities are apparent for children as well. Among youth between 2 and 19 years old, approximately 31%



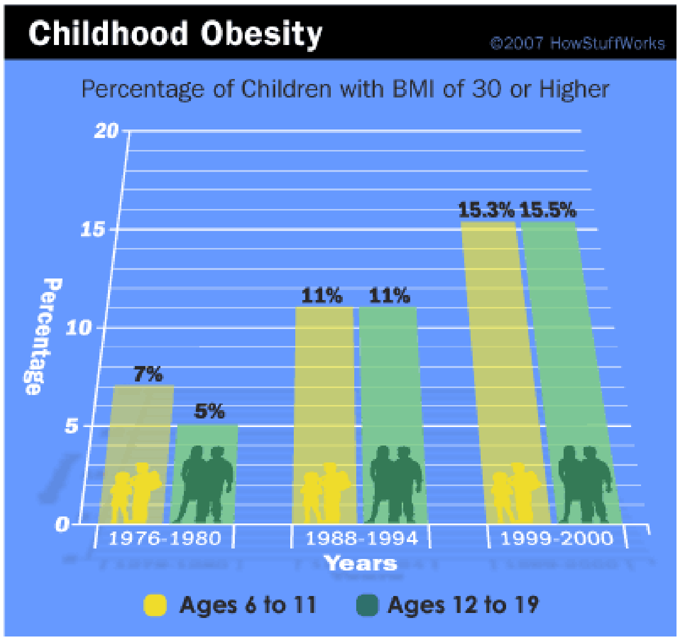
Example of how some sample BMI Numbers would be interpreted for a 10-year-old boy. Courtesy of CDC.org

of whites, 35% of blacks and 38% of Hispanics are overweight. Another 15% of whites, 21% of blacks and 21% of Hispanics are obese, and 10% of whites, 16% of blacks and 16% of Hispanics are extremely obese.[3] Disparities can also be seen across different socioeconomic and education levels. Though there is some variation across racial sub-groups in general, those from lower socioeconomic backgrounds and those with lower levels of educational attainment have a higher prevalence of obesity; this is true for both children and adults.[7]

Health Consequences

The acute and long-term consequences of overweight and obesity are myriad. Overweight puts individuals at increased risk for short-term adverse health diagnoses such as hypertension, elevated low density lipoprotein and triglycerides, and depressed high density lipoprotein.[8-11] Long-term consequences of overweight and obesity include increased risk of diabetes, cancer and cardiovascular disease. Among men, those who are obese are 11 times more likely to develop diabetes, 2 times more likely to develop heart disease, and 1.7 times more likely to develop colon cancer, compared to men of normal weight.[12] Among women, obese individuals are 10 times more likely to develop diabetes, and 1.5 times more likely to develop heart disease compared to women of normal weight.[12] Obesity is also positively associated with colon, breast, endometrial and gallbladder cancer in women.[13] BMI is positively associated with multiple causes of death. An analysis of data from almost 900,000 individuals across four continents showed that among those with a BMI of at least 25, each increase of 5 kg/m² was associated with 30% higher all cause mortality.[8]

The consequences discussed above are the ones most traditionally associated with overweight and obesity; however, there are other outcomes to be



Graph showing the rise in the percentage of children with a BMI of 30 or higher during a 24-year time span. Children ages 6-11 with a BMI that puts them in the "obese" category doubled between the years 1976 -2000. Obese Adolescents ages 12-19 tripled during this same time span. Graph courtesy of howstuffworks.com considered. Though the link between overweight and obesity and orthopedic morbidity is not definitively established, there is some evidence that being overweight is associated with lumbar disc degeneration, as well as complications for patients undergoing thoracic and lumbar spine surgery.[14-16] Higher body mass has also been associated with increased risk for both knee and hip osteoarthritis.[17-19] Ironically, research shows that a higher BMI is actually associated with increased bone mineral density and decreased risk of osteoporosis. However, a more nuanced look at body mass indicates that it is lean tissue that confers greater bone mineral density, as opposed to fat tissue or overall mass.[20,21] This data therefore supports the notion that it is in the best interest of the individual to stay within a healthy weight, which means weighing neither too much nor too little.

A Framework for Understanding Potential Causes of Obesity

The etiology of overweight and obesity is complex and not entirely understood, but at the most basic level the conditions are caused by an energy imbalance in which a person consumes more calories than they expend.[22] This is the proximate cause of obesity, but the imbalance is caused by other factors, including biological make-up and health behaviors in the context of specific environments. In order to organize the putative causes, we will utilize an ecological model (See Figure 1.). Rather than focusing on discrete sources of causation, ecological models propose that health behaviors and outcomes are influenced by a variety of factors that exist on multiple levels, including the intrapersonal,

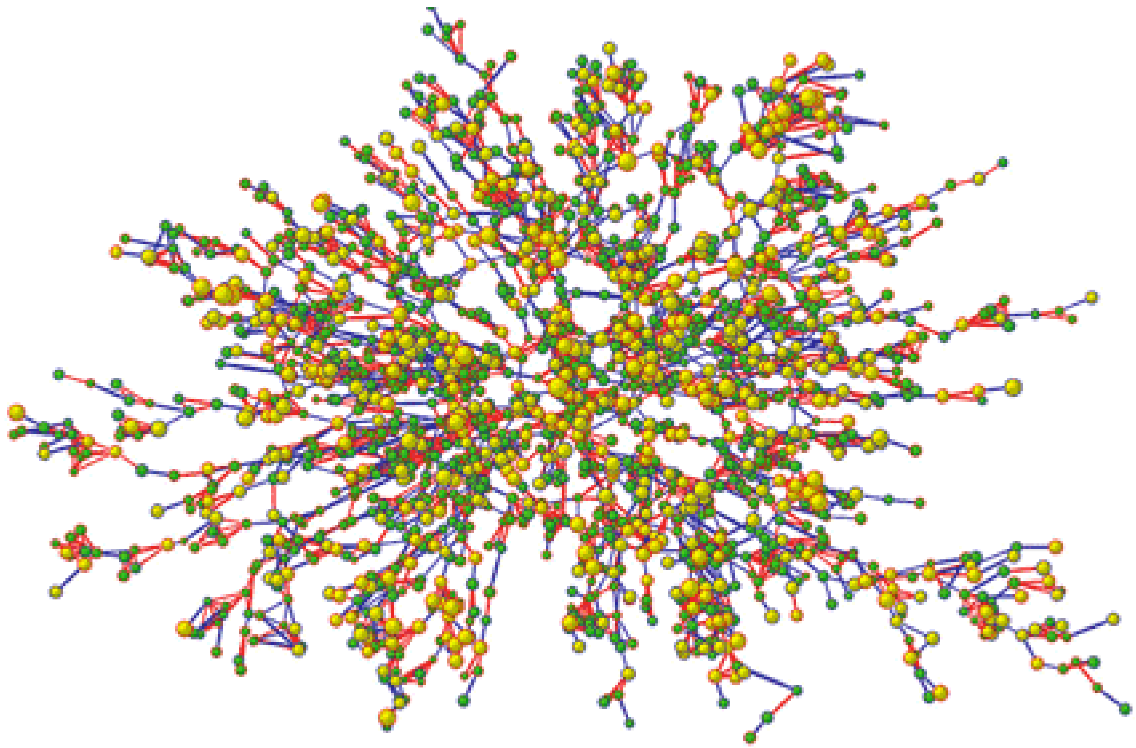


Figure 1. Largest Connected Subcomponent of the Social Network in the Framingham Heart Study in the Year 2000. Each circle (node) represents one person in the data set. There are 2200 persons in this subcomponent of the social network. Circles with red borders denote women, and circles with blue borders denote men. The size of each circleis proportional to the person's body-mass index. The interior color of the circles indicates the person's obesity status: yellow denotes an obese person (body-mass index, ≥30) and green denotes a nonobese person. The colors of the ties between the nodes indicate the relationship between them: purple denotes a friendship or marital tie and orange denotes a familial tie. Christakis, Fowler *The New England Journal of Medicine 357, 370-379(7/26/2007)* Copyright 2007 Massachusettes Medical Society. All Rights Reserved.

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sociocultural and interpersonal, physical environment, and policy.[23, 24] Through interactions with each other, these levels weave a complex "causal web", which ultimately influences an individual's behavior.[22, 25] We will now examine each of these levels.

Intrapersonal

The intrapersonal level subsumes all those factors which reside within the individual, starting with the genetic and biological. It is generally accepted that obesity is highly heritable. Heritablity, the percentage of variance in body mass that can be explained by genetics alone, has been estimated to be between 70 and 80 percent.[26, 27] In the search for explanations of this heritability, recent research has focused on the role of mutations in genes responsible for the leptin–melanocortin pathway, a biological mechanism involved in the regulation of the appetite. Certain mutations may result in decreased production of leptin, blunting an individual's sense of satiety, or fullness, causing them to consume more food.[26-28] In the context of a society with wide access to cheap, energy dense food, individuals possessing these mutations would be more susceptible to overweight and obesity.[27]

Variation in the gene that encodes the ghrelin receptor may also influence obesity. Ghrelin (Figure 2) is a hormone which is involved in stimulating the appetite, essentially making it the opposite of leptin.[29] Mutations in this gene have been associated with obesity.[28-30] Like leptin, variations in ghrelin

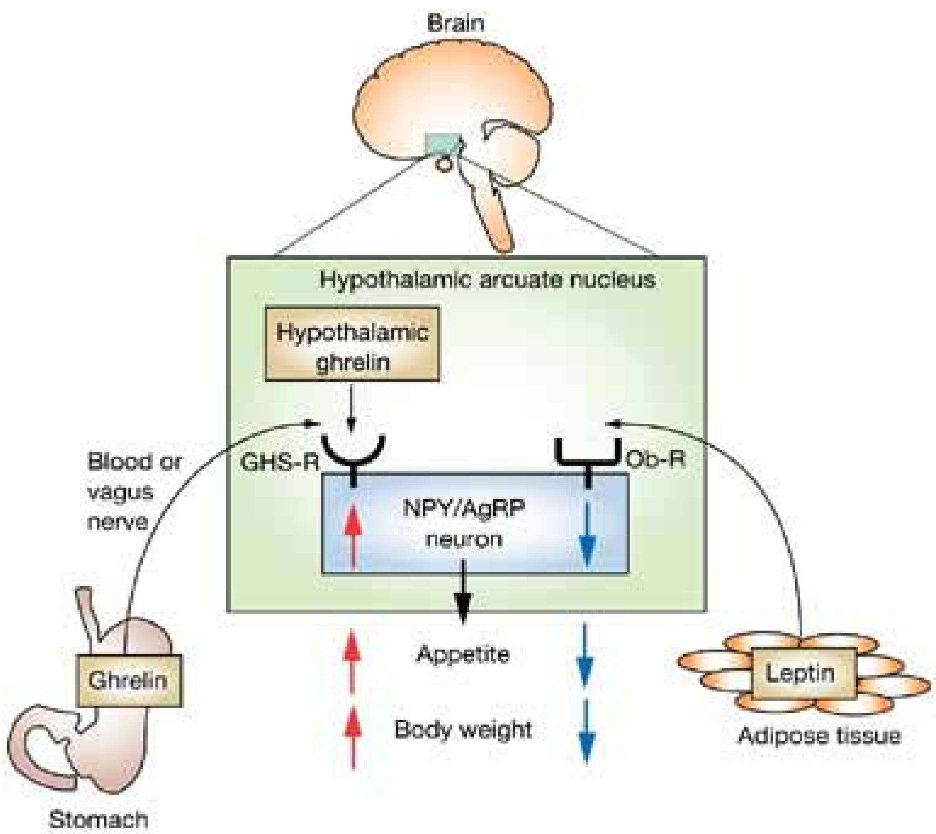
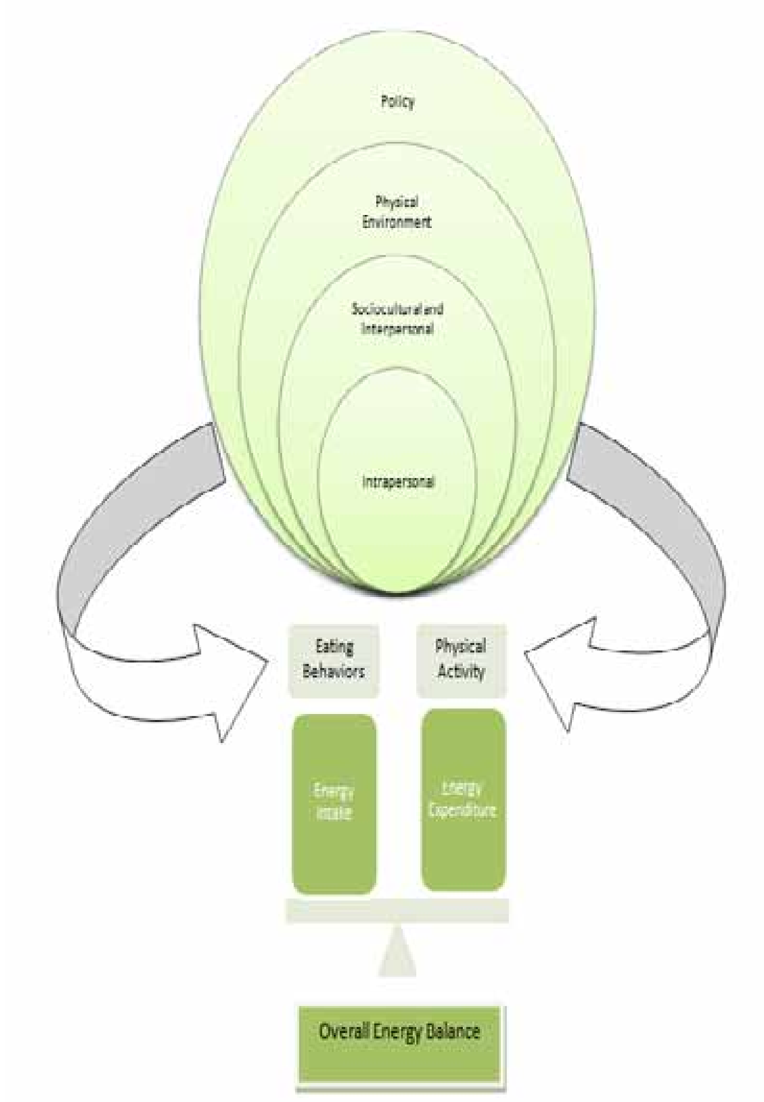


Figure 2. Hypothalamic appetite regulation by ghrelin and leptin showing the signaling pathway of appetite and body fat regulationReprinted by permission from Macmillan Publishers Ltd. *Nature Clinical Practice Endocrinology & Metabolism; Drug Insigh*t: the functions of gherlin and its potential as a multi-therapeutic hormone;Masayasu Kojima, Kenji Kangawa (2006) 2, 80-88 doi:10.1038/ncpendmet0080



Adapted from The Texas Obesity Study Group, 2006.[71]

Figure 3. Ecological Model of Health Behaviors Related to Energy Balance and Obesity

production could make unhealthy food and physical activity environments even more hazardous. The study of the genetics-obesity relationship is still in its infancy, and for all the work that has been done, there are few definitive answers to the questions about how genes affect obesity risk.[26] Nonetheless, it is likely that future efforts to halt the increase in society's collective weight gain will need to account for variations in genetics across individuals.

The intrapersonal level also includes psychological factors ("constructs"), such as attitudes, beliefs, self-efficacy, outcome expectations and expectancies, intentions, and preferences, among others.[24,31] In the case of obesity, there is generally not a direct link between psychological constructs and obesity; rather, these constructs affect behaviors such as physical activity and eating, which in turn affect obesity risk (See Figure 3-Adapted from The Texas Obesity Study Group). Additionally, to the extent that these constructs are involved in the causal web of obesity, they are believed to act as mediators of the effect of an intervention program on individual behavior. That is, some distal factor such as physician counseling, a school-based nutrition program, or a government policy creates change in these constructs, which in turn affect an individual's proclivity to engage in a certain behavior, such as eating a healthier diet. This behavior then becomes the proximate influence on body mass. Because of this indirect, yet still significant, relationship between psychological constructs and obesity, we will focus on how these constructs affect two behaviors strongly linked to obesity: physical activity and eating.

Of the previously mentioned constructs, self-efficacy is perhaps the most prevalent in health behavior research. Self-efficacy is the extent to which a person feels confident in their ability to carry out a certain behavior.[32] Higher levels of self-efficacy have consistently been associated with increased levels of physical activity and healthy eating.[33-38] This strong association has led to the design and implementation of countless public health programs aimed at individuals' self-efficacy levels (and often other psychological constructs).[31, 38] The short-term goal is an increase in health promoting behaviors; and in the longer-term, an increase in energy expenditure and decrease in energy intake, thus restoring overall energy balance and reducing risk for overweight and obesity. Though some programs have demonstrated significant behavior change effects, many have been only marginally

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effective, especially at sustaining changes over time.[24] The lesson is that though a focus on psychological constructs may be a necessary component of behavior change strategies, it is certainly not sufficient.

Sociocultural and interpersonal

The next level up from the individual consists of sociocultural and interpersonal influences on overweight and obesity. These factors operate in much the same manner as the psychological constructs discussed above; they are mediating variables between distal and more proximate causes of obesity. However, these differ in the sense that they involve forces external to the individual and center on his or her interaction with cultural and societal norms, as well as other members of his or her social group, such as family and friends. Constructs in this level include social norms, subjective norms, and social support and influence.[22,31,36]

Aside from the constructs listed above, social networks are an important influence in this level and an area which has generated a great deal of interest among both scientists and lay persons.[39] Put simply, social networks are the connections among a given set of people, and can be a mechanism by which the other constructs in this level are reinforced. Social networks have recently been implicated in the spread of obesity, possibly due to the change in perception of social and subjective norms that occurs when an individual has peers who are obese.[40-42] The change in these norms could influence people to pick up unhealthy behaviors, such as a lack of exercise or a poor diet, and could affect what they perceive to be a normal weight.[43] It seems that within a social network, there are certain individuals who exhibit a high degree of connectivity and therefore exert a disproportionate influence on the other members of the group.[44] The upshot is that social networks are a natural target for health promotion interventions, since there would be a multiplier effect as they spread the behavior change throughout the group.[43,44] However, as with the genetics-obesity research, the reader may want to interpret these findings with a grain of salt. Not all researchers agree that unhealthy

People within the same social network can influence behaviors of others within the same group. This can include unhealthy behaviors such as smoking, drinking, unhealthy diet and lack of excercise.

behaviors, especially those linked to obesity, spread through networks in the same way that truly contagious diseases, such as the flu, do.[39] As more research is done, we will gain a more concrete understanding of how social networks influence behavior and as a result develop better informed public health campaigns.

Physical environment

Of all the levels and constructs mentioned, it is likely that the one which has generated the most interest and novel research recently is the third one, physical environment, often called the built environment. As dissatisfaction has grown with explanations that focus solely on the individual, researchers are increasingly examining the role the physical environment plays in the web of causation.[23] The basic theory behind this position is that though individuals may have the desire and intention, as well as sufficient social support, to exercise and eat healthy there may be structural barriers that prevent them from carrying out the behavior.[24] These barriers include unwalkable neighborhoods, no access to parks or parks in disrepair, heavy dependence on cars, and poor access to healthy foods.[45-48] These factors conspire to make it difficult for people to build physical activity and healthy eating into their daily lives.

One specific aspect of the physical environment that has shown a strong association with physical activity and body mass is neighborhood walkability. No one element determines whether a neighborhood is walkable; rather, it is a construct made up of

numerous constituent parts. These include the presence and condition of sidewalks; the amount of open green space; pleasant, attractive scenery along the way; and the presence of important destinations within a comfortable walking distance, such as grocery stores, schools and centers of employment.[49-52] With these elements in place, residents are likely to get more daily physical activity than similar individuals who live in less walkable neighborhoods.[53,54]

A related aspect is how land is developed in a given area. Since the end of World War II, land use patterns have become increasingly segregated from a geographic standpoint.[55] Some of this segregation is understandable; no one wants heavy industry right next to homes. However, this mentality also results in commercial areas, such as retail space and offices, located far from residential areas, and schools so far from students' homes that they have no choice but to be bussed.[55, 56] This style of land use leads to sprawling developments with fewer opportunities for recreational (e.g. an evening walk around the block) and utilitarian (e.g. walking to the store or to a public transit stop) physical activity and little desire among residents to utilize what resources may be available.[57-60] These situations arise from both conscious decisions by developers and land planning policy decisions of governments. For this reason, policy advocacy is often seen as a potentially effective method to modify the environment in such a way that it is more conducive to healthy living. An example of this can be seen in the smart growth movement. Smart growth is a set of 10 planning principles intended to create more livable and human-scale environments.[61] Examples of the 10 principles include the creation of a range of housing opportunities and choices, mixing of land uses, and provision of a variety of transportation choices.[61] Regulatory bodies around the country are integrating smart growth principles into their land use and zoning ordinances, and a long term outgrowth of this policy shift may be a collectively healthier population.[61,62]

Policy

The fourth and final level concerns policy. Policy has already played a critical role in efforts to improve the public's health, most notably in the campaign to reduce the prevalence of smoking. Strategies to achieve this particular end include bans on television advertising of tobacco, smoke-free buildings and restrictions on tobacco sales to minors.[63] Attention is now turning to how similar strategies can be utilized in the fight against obesity, as can be seen in the anti-tobacco efforts. The policy level tends to focus on modification of environmental factors, because unlike the intrapersonal or the sociocultural levels, policy makers have more direct control over the environment. For example, in the previous section on the physical environment, we can see how policy decisions by those who have authority over land use can potentially create spaces that contain infrastructure necessary

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for physical activity, such as sidewalks and parks. Another example would be policies that tax soft drinks or other foods of minimal nutritional value, i.e. "junk food".[64] The result of this is to make unhealthy foods less appealing through an increase in cost. Other examples include programs that give participants in the federal Women, Infants and Children Program (WIC) food vouchers to be used at local farmers markets, and menu-labeling polices which require restaurants to post information concerning an item's nutritional content.[65, 66] Additionally, policy may work on a more individual level, such as through the health care system. One idea involves modification of insurance policies whereby health care providers would be reimbursed for providing preventive health care to their patients and bonuses based on how many patients do not get sick, thus incentivizing health promotion efforts in the provider's office.[63,67] These efforts could include dietary counseling or exercise prescriptions, services which are not currently a focus of many practices.[67] In addition to the examples above, a great deal of policy work currently focuses on schools, and for good reason: Policy makers have strict control over virtually every decision in schools, and children are a captive audience. In-school policies designed to reduce and prevent obesity include BMI report cards, restrictions on the presence of vending machines, and minimum daily amounts of physical activity.[63, 68]

At this time there is not a tremendous evidence base to support policy approaches vis-à-vis obesity because many potentially promising policies have not been rigorously evaluated.[64,69] Despite this, there is enough evidence from prior work, such as with tobacco, to suggest that policy should play a substantial role in efforts to reduce and prevent obesity.

Future Directions

Even with the tremendous research done in recent years, there are still large gaps in our understanding of overweight and obesity. These gaps are present in both new areas of research, such as genetics, as well as older, more established areas, like psychological and sociocultural constructs. For example, we do not fully understand the interaction between genes and the environment. It is likely that individuals will behave differently in a given environment depending on what their genetic make-up is. Even after accounting for factors like age and sex, not everyone will gain the same amount of weight if they consume a high-fat diet, or lose the same amount of weight if they participate in a given exercise program.[70] Differences at the genetic level complicate broad public health efforts to move more people to a net energy balance. Similar to market segmentation in consumer research, if we can better understand how discrete groups of people will react to exercise and diet interventions, future programs and resources can be targeted to those who will benefit the most. Another area which will require more research is the extent to which factors within each of the four levels impact biological markers and health consequences of obesity. Most research now looks at the effects of intrapersonal, social, environmental, and policy influences on physical activity, eating and BMI itself. Research is lacking on the short- and long-term impact of these potential causal factors on biological indicators (e.g., insulin and cholesterol levels) and health consequences (e.g., diabetes, cancer, heart disease) of obesity. Finally, we need to know more about the interplay between factors in the four levels of the ecological model. Within the causal web, some links are stronger than others. The link between the physical environment and policy, for example, is strong. Less clear, however, is how changes in the environment impact psychological constructs at the intrapersonal level, such as attitudes or self-efficacy. As with gene-environment interactions, more knowledge about how these levels relate to each other will allow us to design and implement programs that are sensitive to the many paths of influence by which external forces can ultimately impact the behavioral choices of the individual.

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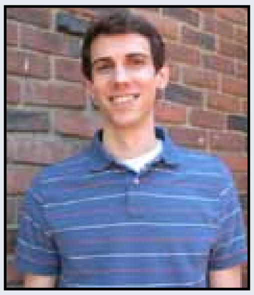

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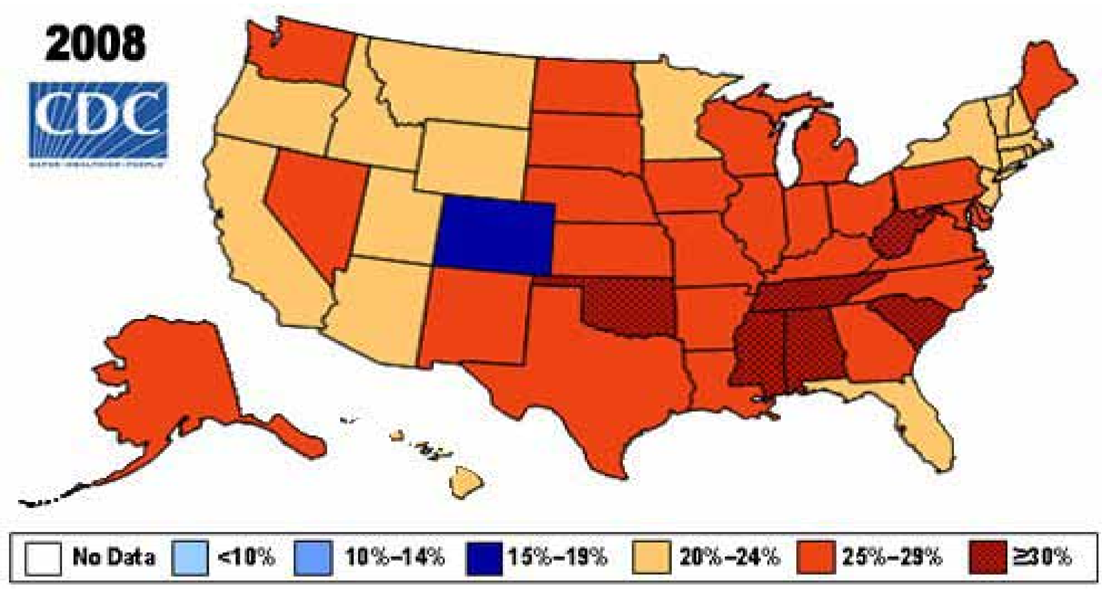
The Tools to Transfrom: What you Need to Know about Bariatric Surgery

Eric D. Pinnar, M.D.

With the rise in obesity, demand for bariatric surgery has surged worldwide. Two surgeries are predominantly offered in the United States: Gastric Bypass and Adjustable Gastric Banding. A new surgical procedure, the Sleeve Gastrectomy, is also gaining acceptance. New techniques have been developed to allow the performance of surgery through a single laparoscopic incision, or even without incision. On average, patients lose more weight through surgery than conventional weight-loss treatments. However, 20-40% of patients gain weight back after surgery.

More than six million people in the U.S. suffer from clinically severe or morbid obesity, a chronic disease with numerous medical, psychological, social and economic consequences. In 2002, an estimated 64% of U.S. adults and 15% of children and adolescents were overweight. In 2005, this number increased to 67%.[1] Increases in obesity are associated with dramatic increases in conditions such as type 2 diabetes and coronary artery disease. In addition, studies have reported that obesity causes more deleterious effects on health than either smoking or problem drinking. The increase in chronic health conditions caused by obesity is comparable to that seen in 20 years of aging. Morbidly obese males between 25 and 35 years old have 12 times the chance of mortality (death) as normal weight men. A morbidly obese adult has only a 33% chance of living to age 65. More than 1,000 people die from obesity and its related health conditions in the United States every single day.[2]

Severe and morbid obesity is defined as a Body Mass Index (BMI) of 35 or more. BMI is a weight and height calculation, (weight in kilograms divided by height in meters squared), which helps determine weight-related health risks of diseases such as diabetes, high blood pressure, hypercholesterolemia, heart disease, joint problems, cancer, etc. Weight loss can significantly reduce these risks, improve health and enhance quality of life. However, numerous studies



U.S. OBESITY TRENDS 1985–2008

In 2008, only one state (Colorado) had a prevalence of obesity less than 20%. Thirty-two states had a prevalence equal to or greater than 25%; six of these states (Alabama, Mississippi, Oklahoma, South Carolina, Tennessee, and West Virginia) had a prevalence of obesity equal to or greater than 30%. Courtesy of the CDC have demonstrated that diets and weight-loss aids do not succeed in helping morbidly obese people achieve long-term weight loss. Many people have succeeded in losing weight only to regain it when they stopped dieting.[3]

If diets, exercise programs and other non-surgical methods fail, patients may want to consider obesity (bariatric) surgery. Several types of bariatric operations exist. Restrictive surgeries prevent the ingestion of large amounts of food, and malabsorptive surgeries reduce the absorption of ingested food. Some surgeries are both restrictive and malabsorptive.

Gastric Bypass

The gastric bypass involves cutting, stapling and rerouting of one's intestinal anatomy to either limit how the body can absorb nutrients or restrict the amount of food a person can consume. The gastric bypass is both a restrictive and malabsorptive procedure because it involves making a 1 ounce stomach pouch and then rerouting the small intestine so that the nutrients eaten are not exposed to the digestive surface of the entire intestinal tract. Because of the 1 ounce pouch, patients can eat very little, and because of the bypassed intestine, they absorb even less of that small amount. The gastric bypass is a longer operation, requires a hospital stay, has a much longer recovery and carries 10 times the risk of the gastric band surgery. Unless patients submit to life long large doses of vitamins and minerals, they suffer from malnutrition, protein malnutrition, anemia, and deficiency in iron, calcium, vitamins B6, B12, D and others. Despite the malnutrition and high risk of the procedure, gastric bypass has an incidence of weight regain in 20-40% of patients.[4-6]

Gastric Band

In contradistinction, the gastric band procedure involves placing an adjustable silicone band around the upper part of the stomach, like a wristwatch, to limit how much food the stomach can hold. Thus, people feel full and are no longer hungry after only a small portion of food. There are two gastric bands in the U.S. market currently, the Lap-Band™ (Allergan Medical) and the Realize®Band (Ethicon Endosurgery). The gastric band surgery is the least invasive and least traumatic procedure of all current obesity surgeries. Unlike gastric bypass and stomach stapling, it does not require cutting, stapling or rearranging of the stomach or intestines. It is safer and healthier than other obesity surgeries because surgical risks and the risk of nutritional deficiencies are lower. With the gastric band, the body's physiology stays intact and all the food's nutrients are fully absorbed. In case of band

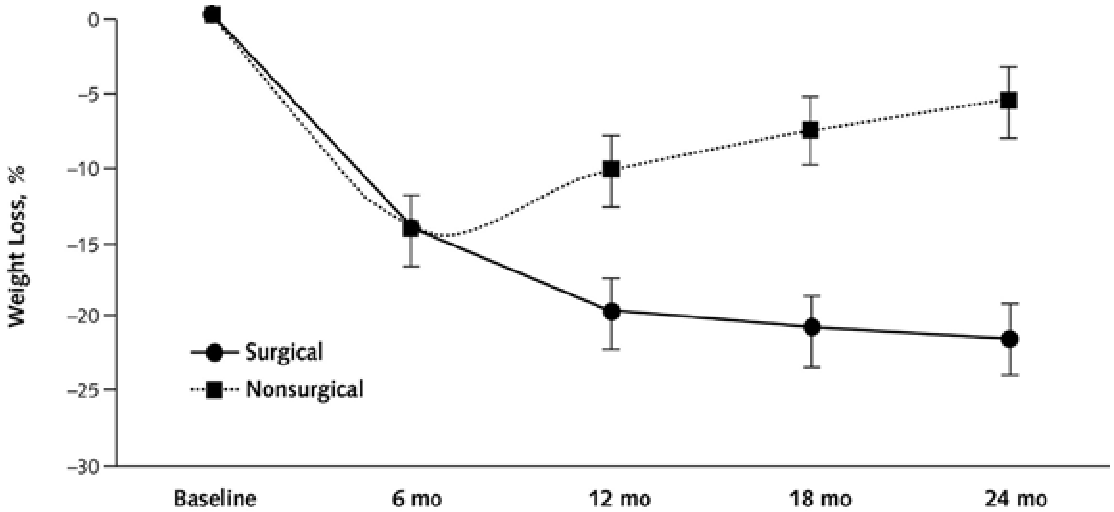


Figure 1: Weight loss through surgical and nonsurgical treatments[3]

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Surgeons Craig Albanese, M.D., John Morton, M.D. and Sanjeev Dutta, M.D. check monitors while performing the first laparoscopic gastric band surgery on an adolescent. Courtesy of Lucile Packard Children's Hospital at Stanford.

removal, the stomach and other anatomy are restored to their original forms and functions.

The procedure takes about an hour and is performed laparoscopically through several tiny incisions using a laparoscope. Recent advances in technology have even allowed some expert surgeons to perform the surgery through one incision. The advantages of the minimally invasive approach include reduced patient pain and quicker recovery. Patients can go home on the same day, just a few hours after surgery. Patients can often return to work in just a few days. Gastric band surgery is the only adjustable and reversible bariatric procedure available in the United States, allowing for individualized patient treatment and slow, steady long-term weight loss. It has become the standard of care worldwide, with over 650,000 procedures performed to date.

Gastric bypass and the adjustable gastric band procedures are the most common in the United States at this time, but a few new procedures are being developed and are gaining interest and popularity. Obesity surgery continues to increase every year in this country. Two years ago, Gastric Bypass was increasing in this country at a rate of about 2% per year. Gastric banding, on the other hand, has been increasing at a rate of about 38-40% per year. This year, 2009, it is projected that for the first time, the number of gastric band surgeries in this country will equal the number of gastric bypass surgeries. Further, it is projected that in 2010, gastric band surgeries will outnumber all other bariatric procedures combined.[7]

Sleeve Gastrectomy

The Sleeve Gastrectomy (or Vertical Sleeve Gastrectomy or Gastric Sleeve) is a new procedure that is getting a great deal of attention in the bariatric arena and is quickly becoming mainstream.[8] Most surgeons refer to it as sleeve gastrectomy. The sleeve gastrectomy seems to combine the reliable weight loss and low maintenance of the gastric bypass with a similar risk profile of gastric banding, but without having to rely on an implanted device. The sleeve gastrectomy works primarily by reducing the size of the stomach so the patient feels full after eating much less food. As a result, the patient consumes fewer calories, and therefore loses weight. In addition, the procedure removes the portion of the stomach that produces a hormone that causes hunger (ghrelin) so patients aren't hungry and don't feel like eating much. This procedure can be an excellent alternative to gastric bypass or gastric banding. Sleeve gastrectomy is a much less complex surgery than the gastric bypass procedure and therefore carries less risk. Unlike the gastric banding procedure, the sleeve gastrectomy doesn't require the use of an artificial banding device to be implanted around a portion of the stomach. However, the procedure is not reversible.

The sleeve gastrectomy was originally derived from the more complex procedure we refer to as the Biliopancreatic Diversion with Duodenal Switch (BPD-DS). Many surgeons who planned to perform a BPD-DS on some of their very high-risk patients would perform the "gastric sleeve" part of the operation which involved removing the majority of the stomach as a first stage. The operation would then be completed 1-2 years later. Those surgeons observed that many patients who had the large reservoir capacity of the stomach removed had excellent sustained weight loss, and therefore the "gastric sleeve" operation began to develop into a procedure in and of itself. The sleeve

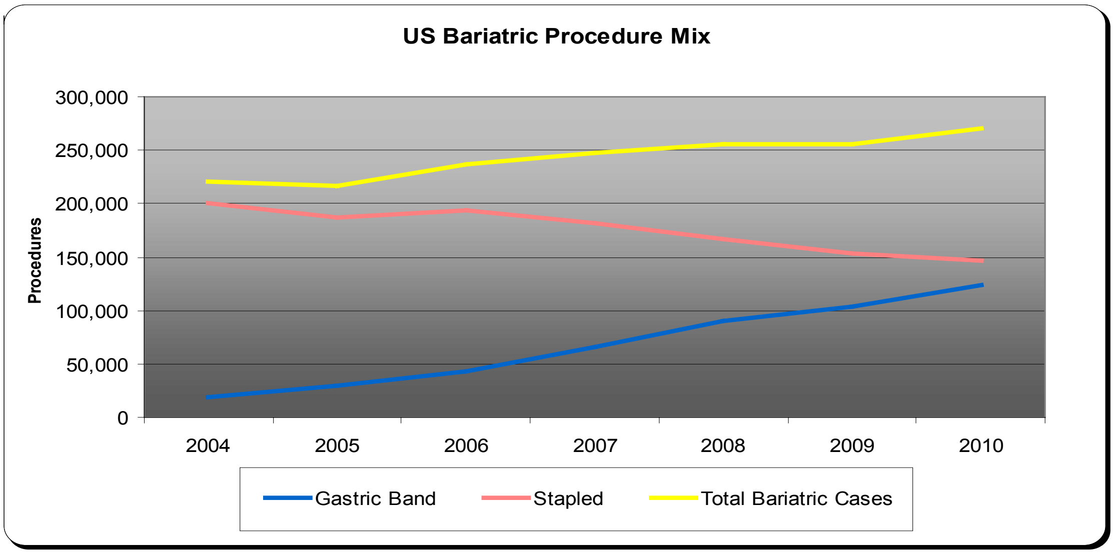

Figure 3- Proportions of Gastric Bypass and Gastric Banding surgeries in the U.S. (Ethicon Endo-Surgery)

gastrectomy has been shown to produce a weight loss similar to the gastric bypass without the substantial risks of gastric bypass. The stomach is reduced in volume, but functions normally so most food items can be consumed. It eliminates the portion of the stomach that produces the hormone that stimulates hunger (ghrelin). There is no risk of marginal ulcer as with gastric bypass. Because the sleeve gastrectomy does not involve "cutting," "rerouting" and "reconnecting" of the small intestine, the surgical risk and the risk of complications are significantly less than those of gastric bypass. Patients therefore do not suffer the complications of the intestinal bypass such as intestinal obstruction (blockage), anemia, osteoporosis, vitamin deficiency and protein deficiency. It also makes it a suitable option for patients who are already suffering from anemia, Crohn's disease and a variety of other conditions that would place them at high risk for surgery involving intestinal bypass. Patients have fewer food intolerances than with the gastric band. Weight loss generally is faster with the sleeve than with the gastric band. There is no implanted device that needs to be adjusted so the follow-up regimen is not as frequent as required for the gastric band. If there is inadequate weight loss, the patient can then be converted to a gastric bypass or a gastric band.

Several studies have reported resolution of obesity related health conditions (co-morbid conditions) in significant numbers of patients, 12 to 24 months after sleeve gastrectomy. In several studies, sleeve gastrectomy patients experienced resolution rates for type 2 diabetes, high blood pressure, high cholesterol, and obstructive sleep apnea that were similar to resolution rates for other restrictive procedures such as gastric banding. Sleeve gastrectomy is a good option for patients with contraindication for gastric bypass or a gastric band. It can be done laparoscopically even in patients weighing over 500 pounds. Due to its significantly lower risk, the sleeve gastrectomy is gaining acceptance as a revisional procedure for patients who have failed with the gastric band and also as an operation for patients with lower BMI (even as low as 30). Limited results with low BMI patients (BMI 35-45 kg/m^2) appear promising as a single standalone procedure.

Technological Advances

Two important technological advances are introduced in bariatric surgery: Single Incision Laparoscopic Surgery (SILS) and endolumenal

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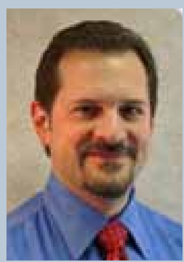
procedures. Laparoscopic surgery typically requires several incisions; placing a gastric band requires four laparoscopic incisions. In contradistinction, Single Incision Laparoscopic Surgery needs only one incision to perform the surgery.[3] This minimizes pain and recovery time.

Endolumenal procedures are completely incisionless and are done "endoscopically" through the patient's mouth like a common upper endoscopy. An endolumenal procedure is already used to perform revision of patients who have failed gastric bypass and are now regaining their weight. Typically, patients who regain weight after gastric bypass may opt for a gastric band (called "Band Over Bypass"). An endolumenal procedure offers another option to revise a failed gastric bypass (Restorative Obesity Surgery, Endolumenal or ROSE). In patients who are regaining weight after gastric bypass surgery, the stomach pouch and/or stoma (the connection between the pouch and small intestine) have stretched in the years since their original surgery, reducing the feeling of fullness after they eat and allowing them to eat more volume. It is possible to create and suture folds into the pouch to reduce its size in volume and at the stoma to reduce its size in diameter through ROSE. This incisionless surgical procedure restores the size of the pouch and stoma similar to the original post-surgery proportions.

Using a new advanced and specialized technology called EOS (EndoSurgical Operating System™) that uses very precise surgical instruments, the procedure is performed entirely through the mouth without making any skin incisions. Because of the lack of external incisions, the ROSE procedure is expected to provide significant advantages to the patient including: less risk than more invasive traditional open or laparoscopic surgery, no postoperative abdominal pain, no significant recovery time, absolutely no scarring, and outpatient surgery (patients go home the same day). This same technology is being trialed as a primary procedure (in patients who have not had any previous bariatric surgery). This Primary Obesity Surgery, Endolumenal (POSE) is entering a 2-year study to evaluate its safety and efficacy for long term weight loss.

The new technology and techniques for SILS and Natural Orifice Transluminal Endoscopic Surgery (NOTES), as well as the new procedures continually being developed, makes this a very exciting time in the field of bariatric surgery.[10] The continued introduction of advanced cutting edge techniques is an important step towards "minimizing" minimally invasive surgery, and towards the ultimate goal of enabling incisionless surgery that will improve patient outcomes.



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Nutrition and The Spine

Danielle Omar, M.S., R.D.

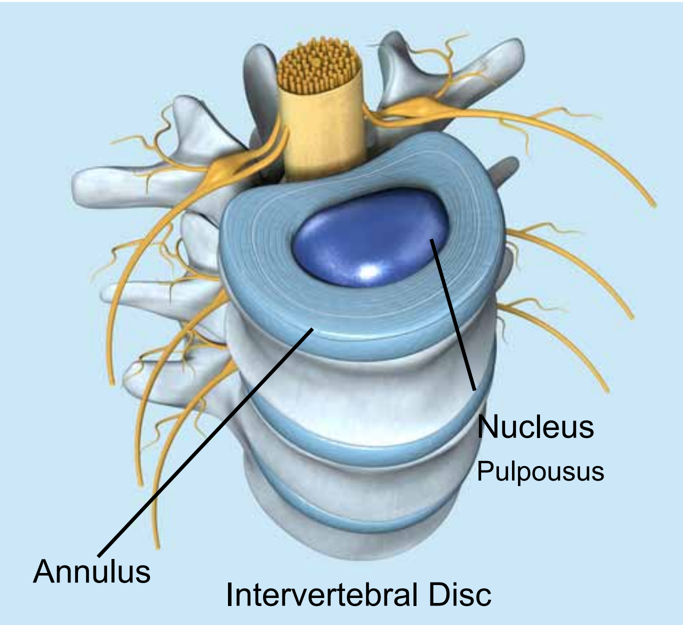
Obesity is a leading cause of preventable death in the United States. It is a national health problem and major medical concern for over 110 million Americans. Obesity is defined by a body mass index (BMI) of 30.0 kg/m^2 or greater, or about 30 pounds or more over ideal body weight. Current Centers for Disease Control estimates indicate 67% of the US population is overweight and 32% is obese, with approximately 26% of men and 28% of women over age 30 suffering with the condition. Obesity not only impacts the health, well-being, and longevity of those affected, it is also a known risk factor for cardiovascular disease, stroke, diabetes, cancer and metabolic syndrome.[1-3] The following article highlights the importance of a proper diet in the prevention of obesity and fostering healthy bones. It emphasizes dietary constituents crucial to a healthy spine and gives recommendations to ensure that these requirements are met.

Obesity can cause injury and damage to the spine. This damage can lead to chronic pain and other symptoms associated with osteoarthritis, rheumatoid arthritis, osteoporosis, degenerative disc disease, spinal stenosis and many other spinal conditions. The American Academy of Neurosurgeons reports that 66% of arthritis patients are either overweight or obese, and obese patients are 4-5 times more likely to be diagnosed with osteoarthritis.[5] Maintaining a nutrient-rich diet that provides all of the nutrients important in bone health is one way to lessen the burden on the spine and increase overall bone health.

The Spine

The spinal column runs from the base of the skull to the pelvis and functions mainly to support the body's weight, allow for its movement and protect the spinal cord. The unique S-curvature design of the column enables the spine to carry and evenly distribute the body's weight.

The spine is divided into three distinct regions (cervical, thoracic and lumbar) of stacked vertebrae. These vertebrae are the building blocks of the spinal column and bear the majority of the weight put upon the spine. Between each vertebrae is a round flat disc that provides cushion and absorbs the pressure produced when walking, running or jumping. Each disc has a strong outer ring of fibers called the annulus, and a soft, jelly-like center called the nucleus pulpousus. The vertebrae are held together by groups of connective tissue, ligaments and tendons.



The spine is also designed to protect the spinal cord. The spinal cord is a column of nerves that connects the brain with the rest of the body, controlling movement and organ function.

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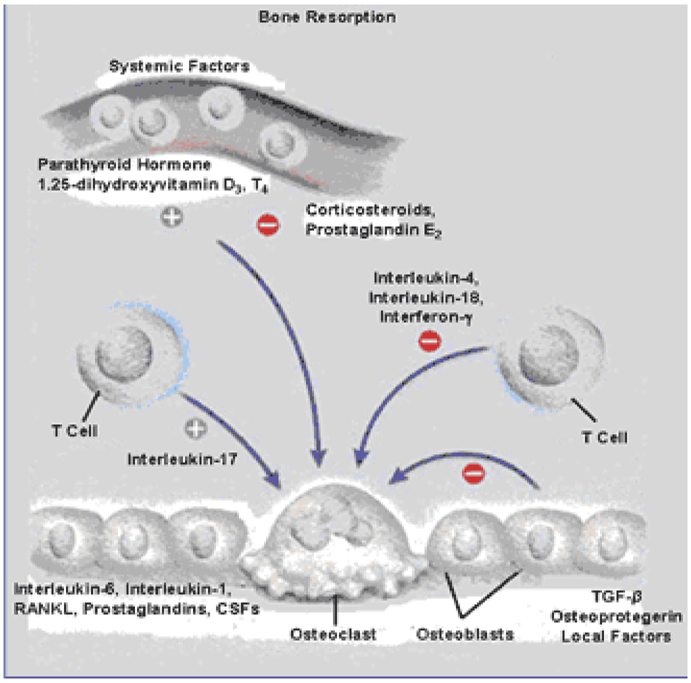


Figure 2. Regulation of bone resorption. Reproduced with permission from Roodman GD. NEJM. 2004;350:1655-1664. Copyright © 2004 Massachusetts Medical Society. All rights reserved.

Bone

The bones of the body are dynamic, living tissues with a collagen-protein construction. It allows them to be both flexible and strong. Throughout life, bones are in a constant state of turnover. Osteoclast cells remove old bone via resorption (Figure 2), and osteoblast cells form new bone. This ongoing process is regulated largely by nutritional status, hormone levels, and the dietary intake of specific nutrients. Mature bone is composed of the nutrients found in protein, fats, vitamins, minerals and water. Approximately 60% of the weight of bone comes from the minerals calcium and phosphate. Much of the remaining weight comes from water and the bone matrix, which is formed before the minerals are deposited, and is often referred to as "scaffolding" for the bone. About 90% of the bone matrix proteins are collagen, which is the most abundant protein in the body. Collagen is a very strong fibrous protein which provides bone with strength and flexibility and is an important component of many other tissues, including skin, cartilage and tendon.

Diet : Bones and the Spine

There are as many as 20 essential nutrients necessary for optimal spine and bone health; all of which work together to keep bones healthy and strong over the course of a lifetime.

Nutrition status will determine bone and connective tissue strength and can predict how efficiently the body will repair its infrastructure of cartilage, ligaments, tendons, and muscle. Many diseases and spinal conditions can be linked to diet. Osteoporosis is an example of a spine-related condition with a clear link to nutritional status.

Example of Osteoporotic bone

Osteoporosis is characterized by low bone mineral density and a structural deterioration of bone tissue which increases fracture risk. Although osteoporosis can occur at any age, it is most common in those over age 50.[5] Many nutrients play a role in maintaining optimum bone mineral density and overall spine and bone health. Among these nutrients are the minerals calcium, phosphorus, magnesium, and potassium; vitamins D, K, B6, B12, and folic acid; essential fatty acids omega 3 and omega 6; and antioxidants.

The importance of dietary **calcium** on bone health is well established. Calcium intake and its proper metabolism are essential for healthy bone development and maintenance, and give bones both strength and rigidity. Intake levels between 1,000 -1,500 mg/day are optimal, with levels below 1,000 mg/day associated with lower peak bone mass in studies.[6]

Phosphorus works in balance with calcium in the bones and blood. 85% of the body's phosphorus is found in bone, where it binds with calcium to form the mineral hydroxyapatite, which gives strength and rigidity to bones. Low intakes of dietary phosphorus can be accompanied by bone demineralization and the loss of calcium in the urine.

Magnesium is essential for absorption and metabolism of calcium. It also helps stimulate the production of calcitonin and parathyroid hormone, which regulate the use of calcium and phosphorus in the body. Magnesium deficiency may play a role in osteoporosis. Research has shown higher intakes of dietary magnesium correlate with higher hip bone densities in men and women.[7-8]

Studies have shown positive associations between dietary **potassium** intake (in the form of fruits and vegetables) and bone mineral density in premenopausal, peri-menopausal, and post-menopausal women and elderly men.[7-8] Potassium-rich foods help buffer acids in the body and maintain acid–base balance by reducing the net acid content of the diet. The effect of a reduction in dietary acid is the preservation of calcium in bones and decreased urinary acid and calcium excretion, which results in increased bone formation and decreased bone resorption.[23]

Vitamin D is a fat-soluble vitamin that is essential for maintaining normal calcium metabolism by increasing its absorption in the intestines and kidney. It aids in preventing bone loss by helping to rebuild new bone and strengthen collagen.

Vitamin K is required for the synthesis of osteocalcin, a bone matrix protein that provides structure to bone tissue. It also aids in the binding of calcium to the bone matrix and has been associated with decreased bone turnover and urinary calcium excretion.

The **B Vitamins** folate, B12 and B6, are important cofactors in homocysteine metabolism. Observational studies have suggested that poor dietary intakes and low blood concentrations of these B vitamins may be associated with decreased BMD, greater bone loss and higher risk of osteoporotic fracture.[7-8] Elevated levels of B vitamins may also stimulate bone formation.

Essential fatty acids (EFAs) are found in the cell membranes of cartilage and bone, and play various roles in bone structure, function and development. EFAs help increase calcium absorption in the GI tract, help reduce and regulate urinary calcium excretion,

and reduce production of the pro-inflammatory eicosanoids in the body. EFAs have also shown to increase calcium deposition in bone and improve bone strength, possibly by stimulating collagen synthesis.[6, 9-11]

Inflammatory conditions involving bone, such as osteoarthritis and rheumatoid arthritis, can also benefit from omega 3 fatty acids EPA, DHA and ALA.[9-13] A 2007 meta-analysis of over 13 studies suggested the eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) omega-3 fatty acids found in fish oil have anti-inflammatory properties that can provide effective relief from joint pain. Taking omega-3 fatty acids for 3-4 months helped reduce joint pain intensity, minutes of morning stiffness, the number of painful or tender joints, and use of non-steroidal anti-inflammatory drugs (NSAIDs).[12] A small US trial confirmed similar findings with walnuts and flaxseed oil, stating a diet rich in these plant omega-3 alpha-linolenic acids (ALA) improved bone health.[13]

Increased antioxidant intakes of carotenoids, particularly lycopene, have also been shown to provide some level of protection against losses in bone mineral density. This protection was seen at the lumbar spine in women and at the hip in men, according to data from a 2009 study in the American Journal of Clinical Nutrition.[12-13]

Dieting can have a largely negative impact on bone health. In fact, lifelong dieting and restrained eating has been shown to put obese women at risk for low bone mass, specifically at the lumbar spine and femur.[5] A much more effective way to achieve optimal bone and spine health is to increase daily intakes of bone-healthy nutrients by concentrating on nutrient-rich, whole foods. *Nutrient rich* foods are those that provide a substantial amount of nutrients and relatively few calories. *Energy rich* foods provide a substantial amount of calories and relatively few nutrients. A nutrient rich diet contains large amounts of bone-building nutrients per calorie consumed. Paying less attention to overall caloric intake and more attention to nutrient density at each meal will greatly increase

Recommendations to increase nutrient density in the diet and to maintain an ideal body weight include:

- **Choose nutrient rich and calorie poor foods most of the time. This includes fruits, vegetables, whole grains and beans; lean protein sources such as chicken, turkey, fish, >90% lean ground beef, tenderloin and round cuts of beef; reduced fat cheese, skim milk and eggs; nuts and seeds**
- **Include a lean protein, healthy fat and high fiber, whole grain carbohydrate with each meal and snack. This balance of nutrients helps curb cravings and increases satiety in between meals**
- **Eat 1.5 oz of dry roasted nuts each day; almonds and walnuts offer the best protection**
- **Limit intake of processed and refined foods and concentrated sweets**

Other strategies to maintain a healthy weight include:

- **Practice plate portioning as a means to control caloric intake. Plate portioning utilizes ½ of a dinner plate for salad greens or fresh vegetables, ¼ of the plate for a lean protein and ¼ of the plate for a whole grain carbohydrate**
- **Eat smaller meals more frequently throughout the day. This prevents dips in blood sugar that cause cravings and/or lead to overeating**

the vitamin and mineral content of the diet, oftentimes while consuming less total calories. An eating and lifestyle focused on choosing nutrient-rich whole foods and daily physical activity can be an effective long term strategy to strengthen bones and connective tissue, alleviate joint pain, and maintain a healthy body weight.

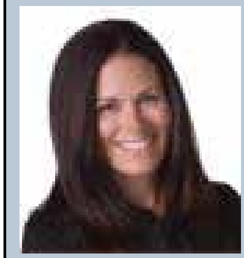
Dietary and Supplement Recommendations:

Although nutrient-rich foods may hold the key to achieving and maintaining optimal bone health, but most Americans do not get adequate intake of the necessary nutrients in their diet. Supplemental vitamins, minerals and fatty acids are the best way to ensure the needs of the body are met when the diet does not provide them. Supplementation may be especially necessary for individuals with specific dietary restrictions, food allergies or decreased absorption of nutrients. At increased risk are the elderly, individuals who spend less than 20 minutes/day in direct sunlight, and those with a spine or bone disease that is linked to nutritional status (e.g., osteoporosis).[7,8,13] Dietary factors which may increase the risk for nutritional deficiencies and potentiate a need for supplementation include:

- Limited intake of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) omega-3 fatty acids and omega-3 alpha-linolenic acids (ALA)
- Limited intake of fruits, vegetables and whole grains
- Limited intake of dietary sources that include calcium, magnesium and Vitamin D (or limited sun exposure)
- Limited intake of dietary protein

Conclusion

The maintenance of a healthy body weight is important to maintaining optimal spine health. A well balanced diet is an effective tool in achieving this goal. Once spine degeneration has started, it is often too late to reverse the situation. By observing a proper lifestyle and diet it is possible to reduce the chances of developing spine. disease.



Danielle Omar, M.S., R.D.

Danielle Omar has extensive experience managing nutritional care at all levels, from neonates up through working professionals. She has served as an adjunct professor for nutritional science classes at the university level. She commands a solid media presence conducting interviews for local news reports and major news and entertainment outlets such as the Washington Post and the Food Network. Her key interests span a variety of areas including family nutrition, sports nutrition, disease prevention, exercise counseling and weight management services.

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Obesity and Excercise

Michael McMurray, P.T., D.P.T., F.A.A.O.M.P.T.

Obesity is defined as a condition in which excess body fat accumulates to a point where it may be detrimental to a person's health. It also describes the recommendations from the American College of Sports to excercise for health and weight loss. The following article highlights the musculoskeletal effects of obesity and focuses on the reduction of calorie intake and exercise as a means of obesity treatment.

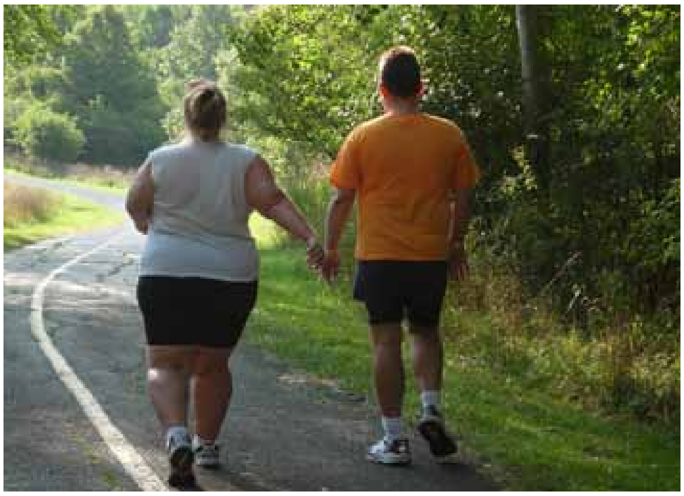
Introduction

Obesity has become an increasingly prevalent pathology in the United States. Between the years of 1980 and 2004 the prevalence of obesity doubled in the United States. In 2005-2006 over one third of individuals over the age of 20 were obese, or over 72 million people, including 33.3% of men and 35.3% of women. Between the years of 2003 and 2006 there was not a statistically significant increase in the prevalence of obesity, however this rate remained at over 34% for adults over the age of 20.[1]

Musculoskeletal Effects of Obesity

Obesity has been associated with increased risk of multiple pathologies including type II diabetes, cardiovascular disease, hypertension, sleep apnea, certain types of cancer and osteoarthritis. Osteoarthritis, or degenerative arthritis, is the most common type of arthritis. It is defined as the breakdown and eventual loss of the cartilage at one or more joints. There have been found to be various risk factors that may lead to osteoarthritis including congenital joint abnormalities, age, repeated stress or trauma, and obesity. Next to age, obesity has been found to be the most powerful risk factor for osteoarthritis. Osteoarthritis of the knees, hips and spine are the most common areas affected with obesity. Research has shown a high correlation between increasing BMI and evidence of osteoarthritis in the knees. One study demonstrated that at a BMI greater than 25 kg/m^2 the incidence of radiographic osteoarthritis is shown to steadily increase as the BMI increases.[2] While there is strong evidence in the literature of a correlation between knee osteoarthritis and obesity, the evidence is not as strong for a correlation between obesity and hip osteoarthritis. However, in a majority of studies a high correlation was found between incidence of hip osteoarthritis and increased BMI greater than 25kg/m^2.

Obesity and low back pain have been correlated in many studies. Although no research has been able to determine the specific mechanism behind the correlation, many theories exist. One theory is that the cause of the low back pain may be due to a low level systemic inflammation. Adipose tissue has been shown to be metabolically active and produces inflammatory and pain modulating hormones. In obese and overweight individuals, greater amounts of these hormones are produced due to the increased amounts of adipose tissue; these hormones have been theorized to be the cause of low back pain. The more widely accepted theory is that the increased mechanical stress placed on the spine results in low back pain. According to this theory, the increased accumulation of adipose tissue causes an increased load through the spine that will initiate degenerative processes resulting in low back pain. Multiple studies have investigated the impact of weight loss on low back pain. Each study agreed that weight loss, even



modest amounts, resulted in a significant decrease in the intensity and frequency of low back pain.[2,3] Additionally, the literature has demonstrated that in patients with spine disease, weight loss resulted in significant improvement in functional health status and less severe pain symptoms.[4]

	Calories burned after one hour of exertion according to person's weight		
Activity	**160 lbs.**	**200 lbs.**	**240 lbs**
Aerobics, high impact	511	637	763
Aerobics, low impact	365	455	545
Bicycling, < 10 mph, leisure	292	364	436
Dancing	219	273	327
Football	584	728	872
Golfing	329	410	491
Hiking	438	546	654
Jogging, 5 mph	584	728	872
Racquetball	511	637	763
Rollerblading	913	1,138	1,363
Rowing, stationary	511	637	763
Running	986	1,229	1,472
Skiing cross-country	511	637	763
Skiing, downhill	365	455	545
Softball or baseball	365	455	545
Tennis	584	728	872
Volleyball	292	364	436
Walking, 2 mph	183	228	273
Walking, 3.5 mph	277	346	414
Water skiing	438	546	654
Weightlifting	219	273	327

*Adapted from Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, O'Brien, WL, Bassett DR Jr, Schmitz KH, Emplaincourt PO, Jacobs DR Jr, Leon AS. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc. 2000 Sep;32(9 Suppl):S498-504.

Exercise recommendations

Basic recommendations for exercise for the average healthy adult to maintain their health and reduce the risk for chronic disease have been released by the American College of Sports Medicine (ACSM) as well as the American Heart Association. The recommendations include performing moderately intense cardiovascular exercise 30 minutes a day five days a week or doing vigorously intense cardiovascular exercise 20 minutes a day three days a week. It is also recommended that an individual perform eight to ten strength-training exercises at eight to twelve repetitions of each exercise twice a week. Moderate intensity activity has been defined as working hard enough to raise your heart rate and break a sweat but still being able to carry on a conversation.[5]

The weight loss recommendations from the ACSM are different. In order to achieve mild weight loss or to prevent unwanted weight gain the average adult should get between 150 and 250 minutes of moderate intensity exercise per week. This amount of exercise, along with a reasonable diet, should burn between 1,200 and 2,000 calories a week. In general, exercising 150 minutes per week will result in 2-3kg (4.5-6.5 lbs) of weight loss, and 225-400 minutes will result in 5-7kg (11-15.5 lbs) of weight loss. In order to achieve more significant amounts of weight loss, more intense exercise or a greater frequency or volume of exercise is needed. Along with the recommended exercise levels, a reasonable diet will help to accelerate weight loss. Additionally, alterations in daily activities can also help to prevent long term weight gain in most adults. Activities such as taking the stairs instead of the elevator, parking further away from the store or wearing a pedometer to take a minimum number of steps a day can assist in weight loss as well as preventing weight gain.[5]

Beginning an exercise program is one of the most difficult steps to take, especially with a busy schedule at work and at home, but trying to incorporate exercise into everyday life is helpful. Here are a few suggestions

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to help to incorporate exercise into everyday activities. Performing short bouts (about 10 minutes) of moderate intensity physical activity has been found to be just as beneficial as 30 minutes of straight exercise. Set aside specific days and times for exercise in order to make it part of your schedule. We don't often think about scheduling exercise like we would a meeting, but it may help. Combine different intensities and types of exercises to make it more interesting. For example, walk for thirty minutes twice a week and exercise on the elliptical trainer two other days a week. Many people think about exercise and immediately think about the gym. A gym membership is not necessary to exercise. There are endless types of home equipment that can be used such as resistance bands, hand weights and an exercise ball to name a few. If space is a problem you don't have to use any equipment at all, if you have a pair of athletic shoes you can begin an exercise program.

An often overlooked, but highly effective, type of exercise program is aquatic exercise. An aquatic exercise program can be especially beneficial for individuals who may not tolerate a land based exercise program. During this exercise program, you are able to increase your heart rate and burn calories, while protecting the joints in your body. Aquatic exercise has been found to be an effective means of exercise for patients with osteoarthritis as well as low back pain and is an effective way for overweight or obese individuals to exercise in a comfortable environment for the joints of the body.[6,7,8]

Physical therapists are medical professionals who are highly trained in exercise prescription. These individuals are able to prescribe an effective and safe program to accomplish weight loss goals, and may be a valuable resource for individuals beginning an exercise program. Additionally, other resources are available that may be useful. These include community fitness centers, personal trainers, physicians and nutritionists as well as many resources on-line. Utilizing these resources, or the many others that are available, will result in positive long term changes in a persons' quality of life. Furthermore, incorporating increased activity and exercise into daily life can result in significant quality of life improvements, weight loss and decreased risk of significant comorbidities in overweight and obese individuals.

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Michael McMurray has seven years of physical therapy experience with a diverse patient population ranging from athletes to the geriatric patients, with varying diagnoses. He has undergone advanced fellowship training in orthopaedic manual physical therapy and is a Fellow of the American Academy of Orthopaedic Manual Physical Therapy.

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Long-Term Outcomes after Multilevel Anterior Cervical Decompression, Instrumentation, and Fusion

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Background: The role of stand-alone multilevel anterior cervical decompression and fusion remains widely debated. Advantages such as direct neurological decompression and restoration of cervical lordosis are countered with concerns about potential complications and construct failures. The purpose of this study is to report long-term results of stand-alone multilevel anterior cervical decompression via discectomy and/or corpectomy with instrumentation.

Methods: Patients who underwent anterior cervical surgery, by one senior surgeon, from 1987 to 2002 to decompress three or more levels by discectomy alone or with corpectomy were retrospectively identified. Patients were contacted for a follow-up questionnaire and clinical visit. Data were collected on patient-derived outcome measures.

Results: One hundred sixteen patients (55 women, 61 men; average age 55.6 years, range 20-83) were identified. Average elapsed time since surgery was 13.4 years. Mean follow-up was 3.8 years (minimum 24 months, range 24–183 months). Of 97 patients alive at the time of data collection, 68 (70%) completed the questionnaire and 43 (44%) returned for clinical follow-up. Neck pain, radicular pain, and headaches improved in 95%, 85%, and 80% of patients, respectively. Approximately half experienced return of pain but not to preoperative levels. Eighty-three percent would undergo the surgery again. Using Odom's criteria, 41% reported excellent, 28% good, 26% satisfactory, and 4% poor results. Fifty-eight postoperative complications were noted in 36 patients, most commonly, dysphagia and recurrent laryngeal nerve palsy. Pseudarthrosis occurred in 19 patients (16%), most often at the C6-7 level. Eleven patients required additional cervical surgery, including six for symptomatic pseudarthrosis and one for symptomatic adjacent segment degeneration.

Conclusions: In this large series, long-term satisfactory results were achieved. Most patients benefited from improvement in pain and neurologic symptoms, and complications were usually temporary. There was a substantial rate (16%) of pseudarthrosis, but few patients required revision surgery and there was a low rate of symptomatic adjacent segment disease.

Keywords: *anterior cervical; corpectomy; decompression; discectomy; multilevel*

Background

The anterior approach to the cervical spine was developed in the 1950s nearly concurrently by Smith and Robinson, Cloward and Bailey, and Badgely.[1,2,3] These procedures have withstood the test of time and as a result, anterior cervical decompression and fusion is commonly performed for surgical management of multilevel cervical disease.[4,5] Anterior approaches, either via discectomies alone or in combination with corpectomies, offer several advantages. They allow direct access to the ventral compressive structures anterior to the spinal cord and the neural foramina, allowing removal of degenerated and protruding intervertebral discs, endplate osteophytes, and hypertrophic uncovertebral joints. The anterior approach also allows for effective correction of pre-existing deformity such as kyphosis and translation. Lastly, interbody bone grafts for fusion combined with instrumentation to achieve immediate stabilization can be readily and safely placed through an anterior approach.

Good results have been reported using the anterior approach for multilevel disease. MacDonald et al. achieved a long-term fusion rate of 97% in patients who underwent a multilevel anterior cervical corpectomy and stabilization using fibular allograft for myelopathy. Groff et al. had a 96% long-term fusion for patients with cervical spondylosis who had 2 or more discectomies with a partial corpectomy.[6-7] However, other series have not had such favorable outcomes, and in some instances, anterior cervical fusion over multiple levels has been associated

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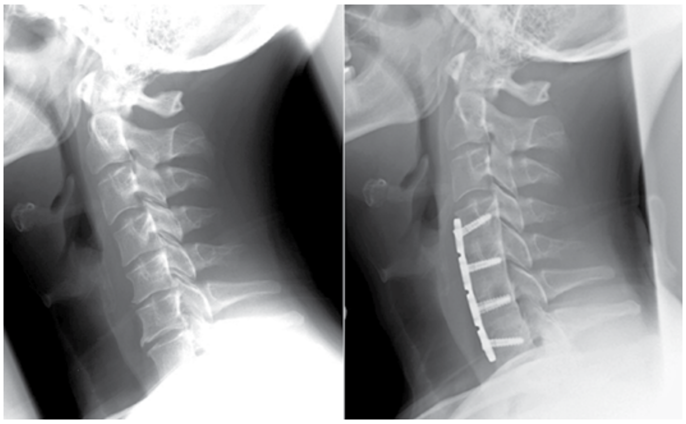

Figure 1. A three-level interbody fusion showing solid fusion, removal of marginal osteophytes, and restoration and maintenance of lordosis.

with significant complications including dysphagia, hoarseness, and instrumentation or graft complications as well as high pseudarthrosis rates.[8-12] Thus, despite the potential advantages of anterior surgery, there is hesitation regarding its use in multilevel cervical procedures as these potential complications are a critical factor in surgical decision-making for cervical spine procedures. No consensus has been reached as to the surgical management of multilevel disease with disagreements among both orthopaedic and neurosurgical spine surgeons on many aspects of the surgical treatment, including the preferred approach, use of instrumentation and indications for fusion.[13] A frequently mentioned concern has been whether anterior only approaches over multiple levels are adequate to maintain lordosis and prevent construct failures without posterior stabilization.

We hypothesized that anterior cervical discectomy with or without corpectomy is adequate in the treatment of multilevel cervical disease without routine need for posterior supplementation (Figure 1). This study was conducted to review the results of multilevel, anterior cervical surgery retrospectively using radiographic, functional and patient-derived outcome measures.

Methods

This University of Utah Institutional Review Board-approved (#10823) study is a retrospective review of patients who underwent an anterior cervical surgery to decompress 3 or more levels for any underlying pathological conditions by discectomy alone or in combination with a corpectomy. Only patients treated by the senior surgeon at our institution during an 18-year interval from 1987 to 2005 were included. All patients were contacted to complete a questionnaire, return for a clinic visit, and obtain current static and dynamic cervical spine radiographs. Demographic information and medical history were collected, including age, sex, indication for surgery, smoking history and prior spinal history, such as presence of inflammatory disease, prior surgeries, ossification of the posterior longitudinal ligament (OPLL), and congenital anomalies. Surgical history included number and specific levels decompressed, type of operation performed (discectomy with or without corpectomy), type of graft (autograft or allograft), and instrumentation used. Lastly, any further cervical spine surgery since the index procedure was recorded.

A typical allograft from a bone bank

Perioperative complications were classified as surgical, instrumentation, neurologic, and medical. Surgical complications were those that were directly due to the procedure such as infection, hematoma, dysphagia, recurrent laryngeal nerve palsy, and cerebrospinal fluid fistula. Instrumentation complications included graft migration and malpositioned screws or plates. Neurologic complications were defined as any new neurologic deficit after surgery.

At latest follow-up, all returning patients underwent a neurologic examination including an assessment of the cervical range of motion. Rotation, flexion, and extension were measured and categorized into one of 3 grades. Eighty degrees of rotation was considered normal (Grade 3), 45° to less than 80° was Grade 2, and less than 45° was Grade 1. Sixty degrees of flexion was considered normal (Grade 3), 30° to less than 60° was Grade 2, and less than 30° was Grade 1. Finally, 50° of extension was considered normal (Grade 3), 25° to less than 50° was Grade 2, and less than 25° was Grade 1. Radiographic outcomes included the presence of an osseous fusion, abnormal motion, adjacent segment degeneration, and instrumentation failure assessed by anteroposterior, lateral, flexion, and extension radiographs. An osseous union was defined as bridging bone across the operated levels on static plain films or no motion between the tips of the spinous processes on dynamic films (flexion and extension).

Patient-derived outcome measures were obtained. Pain was assessed using the visual analog scale (VAS) and was applied to 3 sources: neck, arm and head. Patients were asked to rate their pain before their operation, whether they had any improvement, and their current level of pain. Level of function was determined using the Barthel index and the patient's employment history.[14] Patients were also asked to recollect their level of function before the operation and assess their current level. Finally, their overall satisfaction with the operation was determined using Odom's criteria.[15]

No inferential statistical analysis was planned because we did not specify a null or alternative hypothesis and we did not compare a specific intervention (e.g., discectomy vs. corpectomy). The goal of this study was to evaluate a number of variables in a large study group with long-term follow-up.

Table 1. Descriptive Statistics of Patient Population

Total Number of Patients	116	Specific Levels Decompressed	
Male	61 (53%)	C4-7	49
Female	55 (47%)	C3-7	26
Smokers	29 (25%)	C3-6	25
		C2-5	3
		C5-T1	4
		C2-6	3
		C3-4, 5-7	2
		C3-5, C4-T1, T1-4, C2-7	1 each
Past Cervical History		Number of Patients who Underwent a Corpectomy	54 (47%)
Prior surgery	22	Specific Levels	
Rheumatoid arthritis	(19%)		
Congenital fusions	3		
Ossification of the	3	C5	15
posterior longitudinal ligament	9	C4 and C5	13
		C5 and C6	9
		C6	5
		C4-6	3
		C3-5	3
		C3 and C4	2
		C4, C4 and 6, C6 and 7, T2 and 3	1 each
Indications for Surgery		Graft Material	
Arm symptoms in	46 (40%)	Autograft iliac crest	26 (22%)
addition to pain	21 (18%)		
elsewhere	41 (35%)	Allograft iliac crest	90
Neck pain only	34		
Myelopathy	7		
Spondylotic	4 (3%)		
Traumatic	2 (2%)		
Failed prior fusion	2 (2%)		
Osteomyelitis			
Metastases			
Number of Levels Decompressed		Plating and Screw System	
3	84 (72%)	Caspar	43 (37%)
4	31 (27%)	ABC	33 (28%)
5	1 (1%)	Orion	34 (30%)
		CSLP	4 (3%)
		Atlantis	2 (2%)

Results

Descriptive Statistics

The review identified 116 patients (Table 1). There were 55 women and 61 men, with an average age of

55.6 years (range 20–83 years). There were 29 smokers, and 22 patients had undergone a prior cervical surgery at an outside institution. Three patients had rheumatoid arthritis, 3 had congenital subaxial fusions, and 9 had OPLL. All patients underwent anterior reconstruction with either tricortical iliac crest autograft or tricortical iliac crest allograft. The elapsed time from date of surgery until review was 7 to 21.4 years (average 13.4 years), and the length of follow-up was an average of 3.8 years, with a minimum of 24 months of follow-up. Of the 97 patients alive at the time of the data collection, 68 (70%) completed the questionnaire and 43 (44%) returned for a follow-up visit. Among patients returning for clinical follow-up, the average length of follow-up was 7.5 years. Of those 43 patients, 21 underwent their operation between 1987 and 1995 (21/62, 34%), whereas 22 who had surgery between 1995 and 2002 participated (22/54, 41%). Twelve additional patients (12%) had new radiographic films taken at an outside institution and sent to us but were unable to return for a clinic visit.

The most common indication for surgery was radiculopathy with or without pain in other areas (neck, interscapular area, chest). Other indications, as shown in Table 1, included neck pain only (18%), spondylotic myelopathy (29%), and traumatic myelopathy (6%). Four patients were operated on for failed prior fusions. Three levels were decompressed in 84 patients (72%), four levels in 32 patients (28%), and five levels in one patient. A corpectomy was performed, either alone or in combination with discectomy, in 54 (47%) patients, with the remaining 62 (53%) patients having only discectomies. The most frequently performed operation was a C4-7 decompression, followed by decompression of C3-7 and decompression of C3-6. The C5 level was the most common corpectomy level, followed by C4 and C5 in combination. Allograft was used in 90 (78%) patients. Anterior instrumentation was used in all patients. The Caspar plate (Aesculap, Tuttlingen, Germany) was the most common plating system used (37%), followed by the Orion (Medtronic Sofamor Danek, Memphis, TN) (29%), ABC (Aesculap) (28%), CSLP (Synthes, Paoli, PA) (4%), and Atlantis plates (Medtronic Sofamor Danek) (2%).

Table 2. Perioperative complications

Complication	N		
Neurologic		**Medical**	
		Respiratory distress requiring reintubation	5
New or worsened cord symptoms	0	Tracheostomy	1
C5 palsy	3	Pneumonia	2
		Myocardial infarction	2
		Clostridium difficile colitis	1
Surgical			
Dysphagia not requiring a feeding tube	14	**Instrumentation***	
		Graft subluxation	1
Dysphagia requiring a feeding tube	8	Screw pullout	1
Recurrent laryngeal nervepalsy	11	Plate revision	1
		*- All patients required surgery to revise the instrumentation.	
Cerebrospinal fluid leak	3		
Hematoma	2		
Instability	1		
Infection	1		
Pelvic fracture (bone donor-site)	1		
Total number of complications	**58**		

Outcomes

Perioperative complications: Within 30 days of surgery, 58 complications occurred in 36 patients (31%). As shown in Table 2, the most frequent complication was dysphagia. This occurred in 22 patients (19%) and was severe enough to require a temporary feeding tube in 8 of these patients. A recurrent laryngeal nerve palsy, as diagnosed by direct laryngoscopy, occurred in 11 patients (9.5%). Since 1993, the senior surgeon has routinely deflated and reinflated the endotracheal cuff in an attempt to decrease the risk of a recurrent nerve palsy.[16] Seven of the 37 patients (19%) who underwent surgery before 1993 suffered a palsy, compared with 4 of the 79 patients (5%) operated on after this change.

No patients suffered any spinal cord deficits, but three patients (2.5%) suffered a new C5 root deficit postoperatively, all of which resolved without intervention. Three patients (2.5%) had complications associated with the cervical reconstruction during the first 30 days, including graft subluxation, screw pullout, and plate dislodgment. All of these patients underwent successful revision of their anterior implants without further complication. One additional patient who underwent a C4-7 decompression with corpectomies of C5 and C6 developed instability in the form of listhesis at C7-T1. On postoperative Day 7 she was taken back to the operating room for a C6-T2 posterior fusion and instrumentation.

Pulmonary complications were the most frequent medical complication, occurring in 8 patients, with one patient death due to severe respiratory distress and anoxic brain injury.

Pain: Neck pain, arm pain, and headaches, as assessed using the VAS, were improved initially in 95%, 85%, and 80% of patients, respectively. Approximately half of the patients did experience some return of their pain but not to their preoperative level (Table 3).

Function: Physical functionality was measured using the Barthel index. Fifteen patients indicated they had some deficits in one or more areas preoperatively. At most recent follow-up, a total of 15 patients indicated that they had deficits; of the original 15 patients, 6 had resolution of their deficits. Nine patients reported new deficits, but because the Barthel index addresses patient function overall, these may not have been related to their cervical disease. Employment history is detailed in Table 4. Preoperatively, 50 (74%) indicated that they were working, but 26 (52%) had some restrictions due to their cervical disease. Currently, 28 (38%) patients are employed, with 12 (43%) indicating that their work was restricted in some way because of their neck. Twenty-two patients who were working preoperatively continued to work postoperatively and four unemployed patients returned to work. Of the 40 patients who were unemployed when they completed the questionnaire, 24 (60%) were age 65 or greater and thus the reason for their unemployment is undetermined.

Table 3. Pre- and postoperative assessment of pain using the Visual Analog Scale

Source of pain	Preoperative level (mean)	Initially improved (%)	Returned (%)	Current level (mean)
Neck pain	8.4	95	47	4.6
Arm pain	8.4	85	51	3.9
Head-aches	8.4	80	52	4.9

Table 4. Employment status

Status	Preoperatively (%)	Currently (%)
Employed	50 (74)	28 (38)
Work restricted due to cervical disease	26	12
Unemployed due to cervical disease	5	10

Cervical range of motion was evaluated in 39 of 43 patients returning for examination (Table 5). Rotation was more preserved than flexion or extension. More than 90% of patients had 45° or more of motion. In contrast, 67% of patients had less than 30° of flexion and 60% had less than 25° of extension.

Patient Satisfaction: Patient satisfaction was assessed directly by patient questionnaire and by Odom's criteria. [15] When asked whether they would undergo the same surgery, 83% of patients indicated they would. Using Odom's criteria (Table

Table 5. Range of motion

	Grade 1(%)	Grade 2(%)	Grade 3(%)
Rotation	3 (7)	24 (62)	12 (31)
Extension	26 (67)	4 (10)	9(23)
Flexion	23 (60)	9 (23)	7 (17)

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Table 6. Results of surgery using Odom's scale.[15]

Result of surgery	Definition	N (%)
Excellent	No complaints referable to neck disease. Daily occupations are carried out without any problems.	28 (41)
Good	Intermittent discomfort related to neck disease. Daily occupations are carried out without significant difficulty.	19 (28)
Satisfactory	Improved, but physical activities are significantly limited.	18 (26)
Poor	Unchanged or worse compared with condition before surgery.	3 (4)

6), 41% stated their results from surgery were excellent, 28% reported good results, 26% reported satisfactory results, and 4% had a poor result.

Radiographic Outcomes: In the entire patient population (n=116), an osseous pseudarthrosis occurred in 19 (16%) patients, most commonly at the C6-7 level (12), followed by the C5-6 level (4), C5-7 levels after a C6 corpectomy (2), and the C2-3 level (1). Eight pseudarthroses were diagnosed as a result of motion at the tips of the spinous processes on flexion-extension imaging (2–3 mm), while the other 11 pseudarthroses were diagnosed by a lack of bridging bone on the static plain films or computed tomography. Among the 19 patients with pseudarthrosis, three were smokers (16%), five had undergone a corpectomy (26%), and 16 (84%) had allograft. The ABC plate was used in eight (42%), Caspar in six (32%), Orion in four (21%), and Synthes one (5%).

Eighteen patients (15.5%) showed evidence of instrumentation failure, including screw pullout, plate dislodgement, or screw/plate breakage (Figure 2). Fifteen of the 18 occurred with the Caspar plating system. Adjacent-segment degenerative changes, including fixed and dynamic listhesis, were seen in 23 patients (19.8%). These changes were seen above the fusion mass in 11 patients, below the fusion mass in 6 patients, and both above and below in 6 patients. Additional Surgery: Fifteen patients (12.9%) required further surgery after the index procedure, four within the first 30 days (described previously). Six patients were treated for symptomatic pseudarthrosis—five with a revision anterior approach and one with a posterior approach. Three patients underwent posterior cervical decompression and fusion for recurrence or persistence of neurological symptoms. One patient underwent revision for screw pull-out 3 years after the original operation and one underwent anterior surgery for symptomatic adjacent-level degeneration.

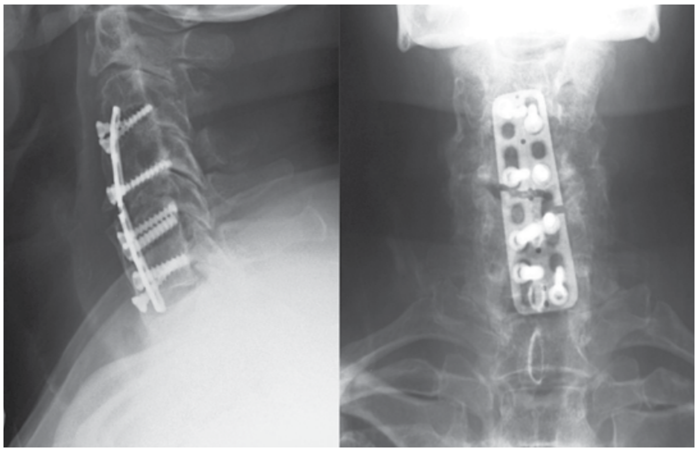


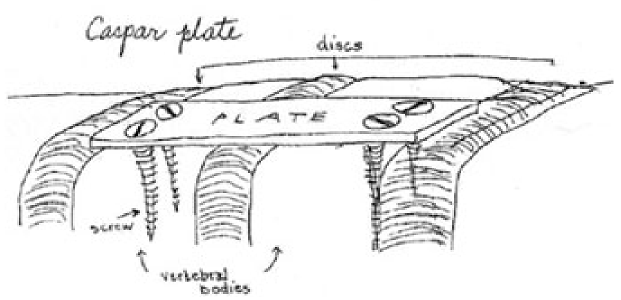
Figure 2. Case example of a patient with implant failure and pseudarthrosis. This 49-year-old man presented with neck pain and radiculopathy and underwent a 3-level anterior cervical discectomy from C4 to C7 using a Caspar plate and allograft. At last follow-up 10 years later, he had a fractured screw, multiple screws that had backed out, a pseudarthrosis, and plate fracture at the C5-6 level as seen on the anteroposterior (left) and lateral (right) plain radiographs. The patient was nevertheless doing well, with resolution of his radicular symptoms, and there was no need for further surgery.

Discussion

Anterior treatment of multilevel cervical disease clearly can result in good intermediate to long-term outcomes. The results of this study demonstrate that significant improvements in pain and functional status can be obtained. Although employment status is generally an important measure, a significant proportion of the patient population was over the age of 65, limiting the usefulness of this measure in this patient population. However, 69% of patients reported good to excellent results, with only 4% reporting poor results by Odom's criteria.[15]

Pseudarthrosis

The results of this report differ from the reported radiographic rates of cervical fusion. Fusion rates for single-level cervical procedures are well above 90%, but the pseudarthrosis rate for multilevel operations has been reported to be as high as 37%, decreasing to 18% with the addition of anterior plating.[12,17,18] Wada et al. reported that 6 of 23 patients who underwent a subtotal corpectomy for multilevel cervical spondylotic myelopathy needed posterior interspinous wiring because of pseudarthrosis.[9] Wang et al. reported a pseudarthrosis rate of 18% in 40 patients who underwent a 3-level ACDF, and Yue et al. had a 30% pseudarthrosis rate in their group of 17 patients.[18, 19] Bolesta et al.reported a pseudarthrosis rate of 53% in 15 patients who underwent 3- or 4-level decompressions; the authors concluded that this was unacceptably high and that a posterior approach should be used instead.[20] In our study, pseudarthrosis developed in 19/116 patients (16%). We deliberately chose a very stringent definition of pseudarthrosis, accepting no motion at the tips of the spinous processes, even with dynamic plating. Because most patients with a small amount (2–3 mm) of motion at the spinous processes are asymptomatic, the use of no motion to define our fusion criterion may overestimate the true incidence of pseudarthrosis. Indeed, symptomatic pseudarthrosis requiring surgical treatment occurred in only six patients (5.1%). Allograft bone was used in 16 of 19 (84%) cases of radiographic pseudarthrosis but was also used in 74/97 (76%) patients with successful fusion. Overall, fusion rate with allograft was 82.2% (74/90) while fusion with autograft was 88.5% (23/26). These results confirm that allograft iliac crest functions as well as autograft. The fusion rate with discectomy-only was 77.4% (48/64), compared with 90.7% (49/54) with corpectomy with or without discectomy. As shown in prior studies, this suggests that the use of a corpectomy may improve fusion rate.[21,22]



Example of a Caspar Plate courtesy of Neurosurgical Foucs; History of instrumentation for stabilization of the subaxial cervical spine; DOI: 10.3171/foc.2004.16.1.11; Ibrahim, Omeis

Instrumentation Failure

Anterior instrumentation was used in all of our patients. Vaccaro et al. reported significant early instrumentation failure and graft migration after anterior cervical decompression and fusion across 3 or more levels and recommended against an anterior-only reconstruction in this setting.[8] Sasso et al. similarly reported early reconstruction failure after 3-level anterior procedures in 71% of patients.[23] In our study, three patients (2.6%) demonstrated either screw or graft failure in the acute setting; only one patient required revision because of screw pull-out. This suggests that variables in technique other than the choice of an anterior approach and use of anterior cervical plating may affect the results.

Late instrumentation complications have also been reported in the literature. Although these complications are often asymptomatic, concern remains regarding displacement of screws and plates in the anterior spine. As plating systems have evolved, the rate of instrumentation complications has dropped precipitously. In our study, the Caspar system used initially, which had non-locking screws, was used in most of the study patients who experienced some form of implant failure. The use of plating systems with locking-screw technologies and dynamic design has helped to diminish the short and long-term complications.

Dysphagia, Dysphonia, and Nerve Root Palsy

Additional complications from multilevel anterior cervical surgery, including dysphagia, dysphonia, and root palsy, have also been reported.[11,16,19,24-26] Edwards et al.performed a retrospective comparison of 13 patients who underwent a multilevel corpectomy against 13 matched patients who underwent a laminoplasty.[11] While minimal complications were reported in the laminoplasty group, complications in the corpectomy group included progression of myelopathy, nonunion, persistent dysphagia, persistent dysphonia, and subjacent motion segment ankylosis. Smith-Hammond et al. found that over 70% of patients who developed dysphagia after undergoing an anterior cervical procedure recovered within 2 months, but 23% required some level of compensatory swallowing behavior up to 10 months after surgery.[24] Audu et al. reported vocal cord dysfunction in 3.2% of anterior cervical fusion patients, while Jung et al. reported recurrent laryngeal nerve palsy in 11.3% ofpatients.[25,27]

Dysphagia occurred in 22/116 (19%) patients in our study, with eight patients (36%) requiring temporary feeding tube placement. All patients had resolution of their dysphagia, with none requiring enteral feeding beyond 6 weeks from surgery.

The rate of recurrent laryngeal nerve injury was 9.5%. Although higher overall than in other studies, the incidence dramatically decreased, from 19% to 5%, after the aforementioned change in endotracheal cuff management, a technique we strongly recommend.[16] C5 root palsy occurred in 2.6% of patients, lower than the average rate of 4.6% in the literature.[28]

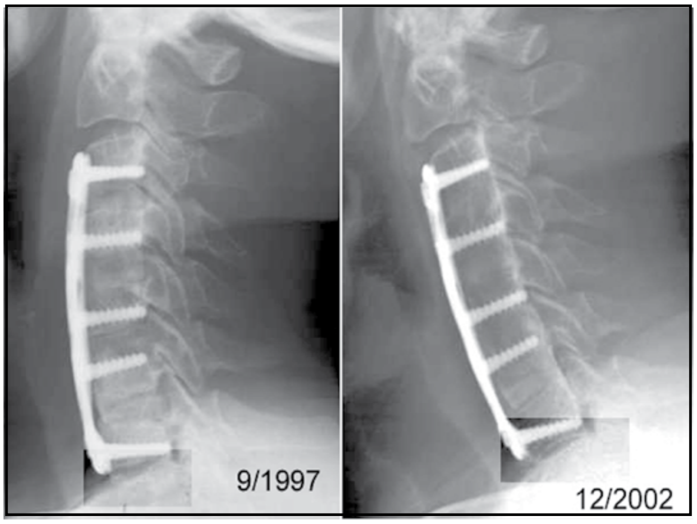


Figure 3. Five-year follow-up radiographs after a four-level fusion for multilevel disc degeneration. Despite the long segment fusion, no adjacent segment disease has developed at C2–3, and the degenerative changes at C6–7, initially present in 1997, have not progressed. The patient is an active individual (marathon runner), and his neck is clinically asymptomatic.

Adjacent-Level Degeneration

Adjacent-level degeneration and disease has been well described in the literature after anterior cervical fusion.[19,29-31] Hilibrand et al.reported that symptomatic adjacent-segment disease occurred at a relatively constant incidence of 3% per year and that survivorship analysis predicted a 26% chance of adjacent segment disease requiring additional surgical intervention at 10 years.[29] The authors demonstrated this risk to be greatest for single-level procedures, although this is often overlooked when their article is cited. Conversely, Kolstad et al. did not find any increased rotational or translational motion at levels rostral and caudal to a single-level fusion at 12 months postoperatively.[32] Ishihara et al. found that symptomatic adjacent segment disease developed in 19 out of their 112 patients (19%), with seven cases (6%) requiring additional operations.[30] Yue et al. noted that revision anterior cervical fusion to address symptomatic adjacent segment disease was required in 16.9% of patients at an average of 41.8 months (range 7–73 months) after the index surgery.[19]

Adjacent-segment degeneration was seen in 23/116 patients (19.8%) in our study. Only one patient (0.8%) required surgery for symptomatic adjacent degeneration. Despite the long fusion construct, which theoretically should increase the stress on adjacent segments, relatively few radiographic and clinical cases of symptomatic adjacent segment degeneration were seen in this study, supporting the data regarding multilevel fusion presented by Hilibrand et al. The best predictor of adjacent-segment disease appears to be pre-existing untreated degenerative levels. In these multilevel cases, such levels, if they were thought to be clinically significant or more than mildly degenerated, were included.[29] This may explain the low incidence of adjacent segment degeneration and the infrequent need for additional-level surgery (Figure 3).

Study Limitations

This study has several significant limitations that must be taken into account. Since this was a retrospective study, our "preoperative" data were obtained from patients after the intervention (i.e., surgery) had taken place. Asking patients to recall their pain level prior to surgery can introduce inaccuracy bias, which would have been eliminated if the study had been designed prospectively. The questionnaire attempted to capture critical outcome, pain, level of satisfaction, physical function and employment; however, it required the patient to recollect events that in some cases occurred many years earlier. This recall bias introduces inaccuracies into the data. However, we believed it was important to gain patient-derived data regarding preoperative symptoms. Another limitation was attrition of patients over time. Of the total of 116 patients, only 68 patients (58.6%) completed the outcomes questionnaires and 43 patients (42.2%) returned for examination. This remaining patient cohort introduces a selection bias, and, thus, conclusions based on data from this smaller cohort may be of limited scope. A third criticism in the design of this study was the selection of outcome measures. The outcome measurements (VAS pain score, Barthel index, Odom's criteria) are not without their own limitations.[15] We chose these because of their easy applicability and prior use in spinal and neurological disorders. In hindsight, patient-derived outcome measures more specific for cervical spinal disorders such as the SF-36, the Neck Pain and Disability Scale, or the Northwick Park Neck Pain Questionnaire could have been used. Nonetheless, any questionnaire could potentially suffer with time. As this patient group ages, pain from causes distinct from the initial cervical degeneration or compression likely occurred and may have been interpreted as "recurrent neck pain."

Finally, this study reports the results of a single surgeon over 15 years. Variations in surgical technique can confound analysis of surgical outcomes and may explain the variable results reported in the literature. By limiting the study to a single surgeon, such variations in technique are hopefully eliminated. These results therefore can be interpreted as showing what can be accomplished but may not reflect the results of a diverse surgeon population using somewhat different techniques.

Conclusions

In our experience, decompressing neural structures, reducing deformity, and fusing and immediately stabilizing the cervical spine across multiple levels by performing corpectomies or discectomies can be effectively achieved with a stand-alone anterior approach. The vast majority of patients experienced long-lasting improvement in their pain and were satisfied with the result of their operation. Immediate complications were not an infrequent event, however, with dysphagia being the most common although generally temporary. Instrumentation-related complications are now rare with modern plating systems. A high fusion rate was obtained and many patients with radiologic pseudarthrosis remained asymptomatic. Supplemental posterior surgeries were rare and, more surprisingly given the presumed increased stress at adjacent segments with the long constructs, symptomatic junctional disease requiring an operation occurred in only one patient.

Abbreviations Used:

IRB, Institutional Review Board; OPLL, ossification of the posterior longitudinal ligament; VAS, visual analog scale

Competing Interests

Ronald I. Apfelbaum, M.D. declares that he has served as a consultant for Aesculap and Integra and owns stock in Medtronic. The University of Utah receives fellowship support from Aesculap, Dupuy and Synthes. Alpesh A. Patel, M.D. is a consultant to Stryker and Amedica. The other authors declare that they have no competing interests.

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Author Contributions:

PK gathered and compiled the data and drafted the manuscript. AP helped draft the manuscript. MAF helped to gather and compile the data. RIA treated the patients, conceived of the analysis, and reviewed the manuscript. All authors read and approved the final manuscript.

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Spinal Research Foundation Regional Research Partners

The Spinal Research Foundation has named fourteen Regional Research Centers across the country that share one core mission: Improving spinal health care for the future. These centers offer the best quality spinal health care while focusing on research programs designed to advance spinal treatments and techniques.

The Orthopaedic and Sports Medicine Center
Contact: *Girard J. Girasole, M.D.*
888 White Plains Road
Trumbull, CT 06611
203-268-2882

The Virginia Spine Institute
Thomas C. Schuler, M.D., F.A.C.S., President
Brian R. Subach, M.D., F.A.C.S., Director of Research
1831 Wiehle Avenue
Reston, VA 20190
703-709-1114

Colorado Comprehensive Spine Institute
Contact: *George Frey, M.D.*
3277 South Lincoln Street
Englewood, CO 80113
303-762-0808

Los Angeles Spine Clinic
Contact: *Larry, T. Khoo, M.D.*
1245 Wilshire Blvd, Ste 717
Los Angeles, CA 90017
310-319-2257

University of Minnesota Medical Center, Fairview
Contact: *David W. Polly, Jr., M.D.*
2450 Riverside Avenue, South
Minneapolis, MN 55454
612-672-7575

Menlo Medical Clinic
Contact: *Allan Mishra, M.D.*
1300 Crane St.
Menlo Park, CA 94025
650-498-6500

New England Neurosurgical Associates, LLC
Contact: *Christopher H. Comey, M.D.*
300 Carew St, Suite One
Springfield, MA 01104
413-781-2211

Inova Research Center
Contact: *Zobair M. Younossi, M.D., MPH*
3300 Gallows Rd.
Falls Church, VA 22042-3300
703-776-2580

MUSC Darby Children's Research Institute
Contact: *Inderjit Singh, Ph.D.*
59 Bee St MSC 201
Charleston, SC 29425
1-800-424-MUSC

Spinal Research Foundation Regional Research Partners

SpineCare Medical Group
Contact: *Paul J. Slosar, M.D.*
San Francisco Spine Institute
1850 Sullivan Avenue
Daly City, CA 94015
650-985-7500

Atlanta Brain and Spine Care
Contact: *Regis W. Haid, Jr., M.D.*
2001 Peachtree Road, NE, Suite 645
Atlanta, GA, 30309
404-350-0106

Southern Brain and Spine
Contact: *Najeeb M. Thomas, M.D.*
3601 Houma Blvd. Ste 400
Metairie, LA 70006
504-889-7200

Hughston Clinic
Contact: *J. Kenneth Burkus, M.D.*
6262 Veterans Parkway
Columbus, GA 31909
706-324-6661

Twin Cities Spine Center
Contact: *James Schwender, M.D.*
913 East 26th Street, Suite 600
Minneapolis, MN 55404
612-775-6200

Princeton Brain and Spine Care
Contact: *Mark R. McLaughlin, M.D., F.A.C.S.*
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609-921-9001

Oregon Neurosurgery Specialists
Contact: *Robert J. Hacker, M.D. and Andrea Halliday, M.D.*
3355 RiverBend Drive
Suite 400
Springfield, OR 97477

Rutgers University Department of Biomedical Engineering
Contact: *Noshir A. Langrana, Ph.D., P.E.*
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732-445-4500

Indiana Spine Group
Contact: *Richard C.Sasso, M.D., F.A.C.S.*
8402 Harcourt Rd
Suite #400
Indianapolis, IN 46260

The Orthopaedic Center of St. Louis
Contact: *Matthew F. Gornett, M.D.*
14825 N. Outer Forty Road, Ste 200
Chesterfield, MO 63017
314-336-2555

South Coast Orthopaedic Associates
Contact: *Aleksandar Curcin, M.D., M.B.A.*
2699 N. 17th Street
Coos Bay, OR 97420
541-266-3600

Allegheny Brain and Spine Surgeons
Contact: James P. Burke, M.D., Ph.D.
501 Howard Avenue, Building E-1
Altoona, PA 16601
814-946-9150

Neck and Back Pain Affects Millions

The Spinal Research Foundation has made remarkable progress in scientific research associated with neck and back pain. Located in Reston, Virginia, the Foundation collects data relative to patients' treatment and outcomes and has embarked on projects designed to better understand the biochemistry of neuropathic pain and develop new drug and surgical regimens to address it. The Foundation continues to expand its research efforts, partnering with other research institutions to further the advancement of spine related research. The Spinal Research Foundation has been involved in numerous studies:

- ***The use of novel perioperative drug therapy to improve surgical outcomes.***
- ***The evaluation of medical devices for the relief of back pain.***
- ***The evaluation of analgesic drug regimens.***
- ***The development of non-operative techniques to resolve disabling neck and back pain.***
- ***Investigating the use of BMP (Bone Morphogenetic Protein) in minimally invasive spinal surgery to minimize post-operative pain and dysfunction.***
- ***The development of cervical and lumbar disc replacement technologies.***
- ***The development of disc regeneration technology through the use of stem cells derived from the bone marrow.***
- ***The investigation of lactic acid polymers to prevent fibroblast in-growth in surgical wounds.***
- ***A nation-wide multi-center prospective spine treatment outcomes study.***

The Spinal Research Foundation is an international non-profit organization dedicated to improving spinal health care through research and education. The Foundation collaborates with spinal research centers of excellence around the world to prove the success of traditional approaches, as well as develop new techniques and technologies. These results are shared with both the medical profession and the general public to improve the overall quality and understanding of optimal spinal health care.

More than 85% of the population will suffer from severe neck and/or low back pain during their lifetime. Eight percent of these people develop chronic pain, which means that at any given time, 25 million people in the United States are directly affected by this condition and many more indirectly. Techniques to cure, manage, and prevent this limiting and disabling condition need to be developed. Educating the public, health care providers, and insurance providers is the first step in advancing spinal health care.

You can help!

The Spinal Research Foundation is America's leading non-profit health organization dedicated to spinal health. Friends like you have made it possible for us to make huge strides and groundbreaking research discoveries. Join us in our mission to promote spinal health. Support cutting edge research by making a donation to the Spinal Research Foundation.

Support cutting edge reseach

- Visit www.SpineRF.org to make a secure online donation.
- Call (703) 766-5405 to make a donation over the phone.
- The Spinal Research Foundation is a non-profit 501(c)(3) organization. Donations are tax deductible.

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- Sign up online for our free e-newsletter and visit our web-site often to keep up-to-date on the Foundation's activities and research breakthroughs.

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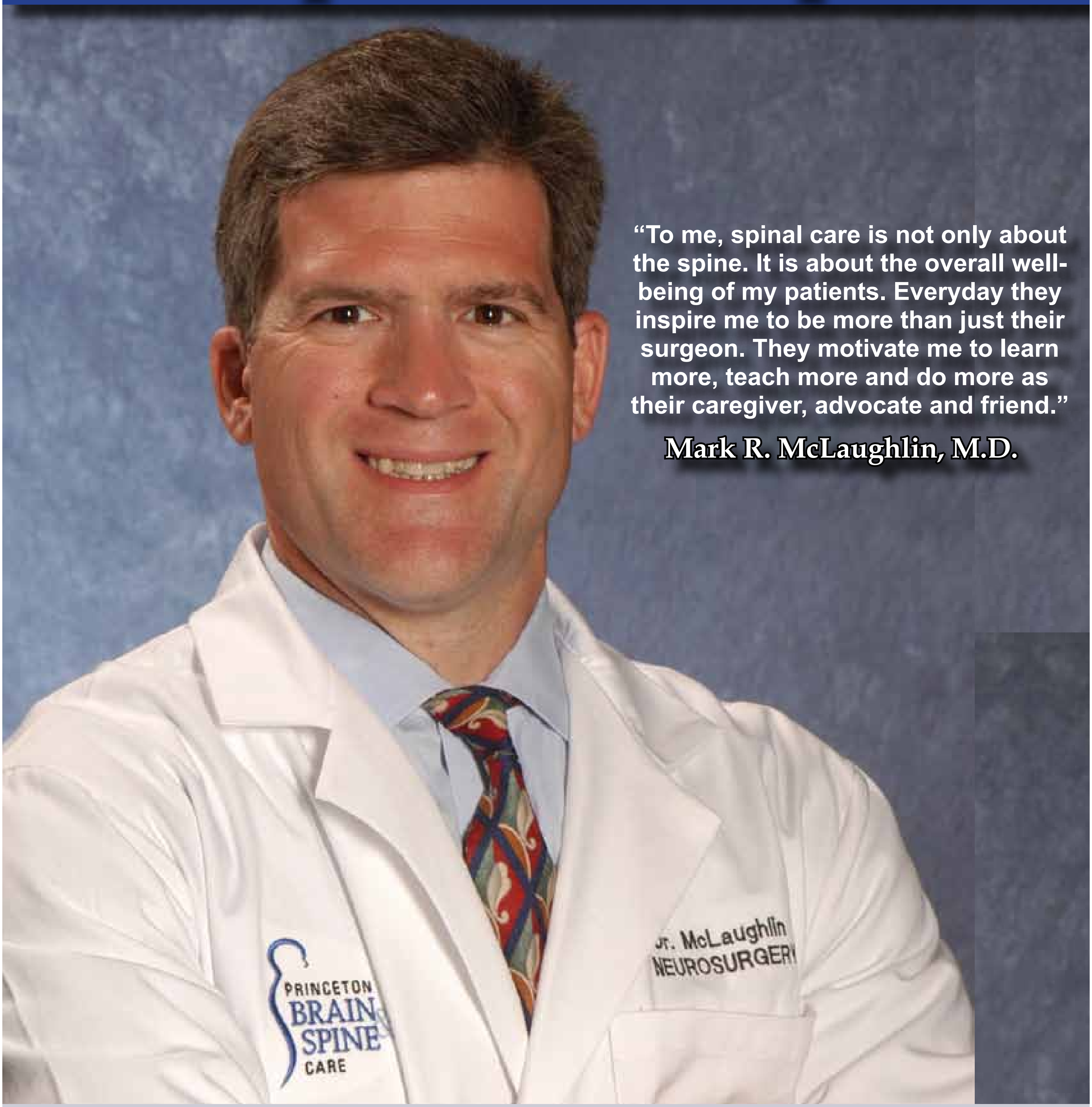
Spinal Champion



"To me, spinal care is not only about the spine. It is about the overall well-being of my patients. Everyday they inspire me to be more than just their surgeon. They motivate me to learn more, teach more and do more as their caregiver, advocate and friend."

Mark R. McLaughlin, M.D.

The Spinal Research Foundation recognizes outstanding clinicians and researchers in the field of spine research and profiles them as Spinal Champions. These dedicated spine care professionals embrace excellence in both research and education, contributing significantly to improvements in the diagnosis and treatment of spinal disorders. This issue recognizes Mark R. McLaughlin, M.D., F.A.C.S., Neurosurgeon at Princeton Brain and Spine Care who practices neurological surgery with a focus on spine disorders.

Thank You!

The Board of Directors of The Spinal Research Foundation is grateful for the continued investment of our donors and extends its appreciation to all who have contributed.

Through the generous support of our donors, The Spinal Research Foundation has been able to significantly expand the scope of our scientific research and educational programs. These gifts have been utilized to establish scholarship programs and embark on projects geared toward understanding the mechanism of spinal diseases, and develop new treatments for these conditions. This work would not be possible without the support of our donors.

To make a donation in order to improve the quality of spinal health care in America visit:

www.SpineRF.org

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