Development of a Pedal Powered Wheelchair

R. Dix and R. Pal
Illinois Institute of Technology, Department of Mechanical and Aerospace Engineering

D. A. Brown and M. Makhous
Department of Physical Therapy and Human Movement Sciences, Feinberg School of Medicine, Northwestern University

A first student project to put pedals on a wheelchair for exercise and propulsion was unsuccessful. The need remained and in June of 2005 the "Eureka" event occurred. Seeing a five-year-old on her training-wheel-equipped bicycle suggested that a fifth wheel could be added in the center between the wheelchair's two large rear wheels, and a mast supported by the fifth wheel's axle could extend forward to support a front axle and pedal set. A chain drive completed the propulsion system. There are no pedal-powered wheelchairs currently on the market. Around 2001 a product (EZChair) without retractable pedals was on the market but withdrawn. A team at the University of Buffalo invented and patented a pedal-powered wheelchair in 1993 (US Patent 5,242,179), but it was not commercialized. Also, a Japanese company designed and built a series of fifth-wheel wheelchair designs. Between 2006 and late 2008 we built many prototypes incorporating geometries that permitted retracting the pedal. For compactness a "Pedalong" with three telescoping tubes was built but it proved impossible to secure tightly. In the next design twin telescoping tubes passing above and to the rear of the rear axle provided the desired extension. A clamp at the front of the outer tube provided tightness of the assembly. In the Northwestern research program (see below), there was some success, but awkwardness in operation prevented commercialization. In October 2008 a major design change from a fifth wheel in the center to a powering of the two standard rear wheels was begun. This required a new chain path geometry and addition of a differential to the drive train. With the new design user control, arm-powering and braking through the rear wheels is retained, and chair stability is improved. Twelve individuals with chronic post-stroke hemiplegia (>6 months post-stroke event) participated in a study to examine the metabolic energy expended when participants performed a 6-minute walk test, a 6 minute leg-propelled wheelchair trial (using the Pedalong), and a 6 minute arm-propelled wheelchair trial. VO2, VCO2, and distance traveled were measured using a portable metablic cart system and wheel-based distance measurement system. The Pedalong and walking trials showed equivalent oxygen consumption levels, but manual pushing was, on average, significantly less. All three modes (walking, leg-propelled and arm-propelled) resulting in similar distances traveled within the 6 minute period. The leg-propelled trials generated the greatest amount of VCO2 during expiration compared with the other modes. This means that more of the available oxygen is being utilized (metabolized) during the leg-propelled mode and so, a greater number of calories were being burned during this 6-minute test.

Material Orientation Artifact Studies in Magnetic Resonance Imaging

S. McDonald, N. Knutson, and A. Erdman
University of Minnesota, Minneapolis, USA

With the increased interest of MRI guided interventional procedures in modern medical treatments, image distortion and artifact formation based on material selection and orientation within the MRI scanner are central concerns for precise object localization. The goal of this study was to illustrate the artifact behavior of materials with various magnetic susceptibilities and radio frequency conductivity values corresponding to object orientation relative to the primary magnetic field. To test the effects of orientation on image distortion and image artifacts, 0.125 inch cylindrical test samples of various materials were imaged using a clinical Siemens 3 Tesla MR scanner. Modern medical instrumentation and surgical utensils are typically made from highly paramagnetic materials (e.g., titanium, nitinol, or stainless steel) which also have high RF conductivities. The combination of these two material properties cause both primary magnetic field (B0) and RF field (B1) inhomogeneities which lead to local image distortions. A change in the local magnetic field induces errors within the slice selection gradient, as the precessional frequency of the proton nuclei in the desired region of interest will not correspond to the exact spatial location on the object and will excite a broader region due to the RF conductivity of the material. Conversely to more traditional surgical materials, diamagnetic materials (e.g., bismuth, pyrolytic carbon, water, most plastics) are free from the susceptibility artifacts due to B0 inhomogeneities and thus offer a level of MR compatibility that traditional materials cannot. A specific testing phantom was built to fit a clinical wrist coil. The phantom consisted of an aqueous solution of gadolinium and copper sulfate to increase image contrast and a rotatable turret post for sample positioning. The particular materials studied were chosen to demonstrate the wide variation in both magnetic susceptibility values and RF conductivities (e.g., 6A1-4V titanium, 316L stainless steel, carbon fiber, 6061 T6 aluminum, brass, copper, beryllium copper). ImageJ software measured the overall pixel area and major dimension of each MR image artifact at 0, 45, and 90 degree orientations of each test sample relative to B0. The results of the measurements indicated measurable increases in signal are of the paramagnetic and highly conductive test specimens orientated orthogonal to the primary magnetic field. For instance, two common medical grade materials such as 316L stainless steel and 6Al-4V titanium resulted in artifact area increases of $770 \pm 10\%$ and $234 \pm 10\%$, respectively, relative to the actual cross sectional area of the sample. Conversely, the more diamagnetic materials, carbon fiber and beryllium copper demonstrated increased artifact areas of $8 \pm 10\%$ and $12 \pm 10\%$, respectively. Errors in artifact area percentage growth measurement are primarily attributed to manual image segmentation and variation in coil positioning within the MRI bore. The results indicate that MR image artifact size and object distortion characteristics can be influenced by both material selection and object orientation relative to the primary magnetic field. In the interest of accurate navigation of image guided equipment and devices, interventional devices should be tested for image distortion in multiple orientations. This work is supported by MIMTeC, a National Science Foundation Industry University Collaborative Research Center and by NIH Grant P30 NS057091.

Downloaded from http://asmedigitalcollection.asme.org/medicaldevices/article-pdf/3/2/027520/5569708/027520_1.pdf by guest on 24 May 2022

 Copyright © 2009 by ASME