HYBRID VACUUM PUMP FOR VACUUM-ASSISTED SUSPENSION IN TRANSFEMORAL PROSTHESSES

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INTRODUCTION
Evidence suggests that vacuum assisted suspension (VAS) reduces relative motion between the residuum and prosthetic socket to improve force transmission, comfort and soft tissue health (1, 2). VAS is achieved through evacuation of air between the liner-clad residuum and prosthetic socket by vacuum pumps. Commercial pumps often have a tall build height and can be noisy (electric) or require extended time to generate vacuum (mechanical). There is need for a low-profile pump for use with transfemoral prostheses that works quietly and quickly generates vacuum when desired while conserving battery life. This study describes a hybrid vacuum pump, known as Northwestern University Hybrid Integrated Prosthetic Pump Initiative (HIPPI), that was developed to address this need by integrating electric and mechanical function into a single design (Patent US9066822, Pending 62/214,560) (3).

METHOD
The HIPPI concept relies on combined electric and mechanical function to create vacuum within the liner-socket interface. Two prototypes were developed (first with a bladder and then with a diaphragm); the bladder pump, was evaluated on the bench, and during walking using prosthesis simulators as well as transfemoral prostheses.

Subjects: Able-bodied individual (simulator test) [35 years, 185 cm, 78 kg]; unilateral transfemoral amputee (prosthesis test) [54 years, 183 cm, 97.5 kg].

Apparatus: A digital pressure gauge (DigiVac, Matawan, NJ) monitored vacuum during all testing with the bladder pump.

Procedures: Bench testing: A hydraulic machine (Instron, Norwood, MA) subjected the HIPPI to 300 cycles of 10 mm displacement. Simulator testing: Subject walked (0.53 m/s) for 10 min after the electric pump generated 17 in-Hg. Prosthesis testing: Subject walked (0.53 m/s) for 10 min after the electric pump generated 17 in-Hg using two pumps: 1) LimbLogic electric pump (Ohio WillowWood, Mt. Sterling, OH), and 2) HIPPI bladder pump.

RESULTS
Bladder and diaphragm pump prototypes and vacuum gauge pressure results for the different conditions of testing the bladder prototype are shown in Figure 1.

DISCUSSION
Testing demonstrated that the HIPPI bladder prototype can rapidly generate vacuum through the electric system, and sustains vacuum during walking through the mechanical system to minimize electric reactivation and maximize battery life. Off-axis loading of the bladder during walking encouraged a redesign that included a diaphragm component that, due its architecture, provided for more reliable function.

CONCLUSION
Testing has confirmed proof-of-concept that the HIPPI can generate VAS in transfemoral prostheses.

CLINICAL APPLICATIONS
The HIPPI has utility for users who experience excessive time to create sufficient vacuum when using only a mechanical pump (e.g., elderly) and risk incurring residuum trauma, or who desire immediate use of their prosthesis post-donning (e.g., engaging in sporting activity or the military).

REFERENCES

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