The glenohumeral joint’s unique characteristic of having the largest degree of motion in the human body unfortunately also causes it to be much more susceptible to a wide variety of injuries, many of which exhibit the same variety of symptoms, making it that much harder to pinpoint the true cause of the damage. In order to achieve true functionality of the hydraulic distension device, it will be necessary to understand what sort of intra-articular pressure vs. infused volume profiles are expected to be seen not only for Adhesive Capsulitis, but other injuries as well due to the possibility of mistakenly diagnosing a patient with stiff shoulder syndrome, when they really have a rotator cuff tear or a contracture, for example. Several different journal articles were examined in order to better understand the intra-articular pressures profiles and how they change based not only on the type of injury, but the position of the arm itself and the respective consequences. The article titled “The relation between the position of the glenohumeral joint and the intra-articular pressure” by Inokuchi, et al. (1997) examined several fresh cadaveric shoulders in order to determine the intra-articular pressure changes based on the adduction/abduction/rotation of the humerus with respect to the scapular plane. It was observed that the initial pressures of the shoulder capsules had an average value of -67.8 mmHg, with the key piece of information being that the values obtained were negative with respect to the atmosphere. This negative pressure is a key factor in providing proper stabilization of the overall shoulder joint complex and must be maintained throughout the distension procedure in order to ensure optimal healing.

Inokuchi was also able to obtain the average angle of 20° abduction which yielded the minimal average intra-articular pressure of -82.9 mmHg. When it came to the rotation of the humerus, it was also determined that an average minimal pressure of -70.7 mmHg was obtained when the humerus was at a neutral rotation. Another key piece of information
obtained is that the intra-articular pressure decreased at a rate of about 39.9 mmHg per 1 kg of weight added to the end of the freely hanging humerus. This could be really useful to implement in the device since it is possible to determine the weight of a patient’s arm as a percentage of their overall weight, and then use this information to better determine the degree of influence their arm has in changing their intra-articular pressure. The pressure results for both the abduction/adduction and rotation of the humerus are shown above in Fig. 1.

In the journal article “Dynamic analysis of intra-articular pressure in the glenohumeral joint” (Hashimoto, et al., 1995), the intra-articular pressures of 180 patients were examined again based on the angle formed between the arm and the trunk. What is really useful from this article is that the patients included not only healthy shoulders, but also patients diagnosed with two types of shoulder contractures, types 1, 2, and 3 rotator cuff tears, unstable loose shoulders, rotator cuff lesions, and recurrent anterior dislocations. As previously mentioned, a shoulder injury could have symptoms that cover a wide range of complications at a first glance, but Hashimoto, et al. has shown that each type of injury has its own unique pressure vs. arm-trunk angle profile. These profiles, several shown in Fig. 2 below, can then be implemented into the hydraulic distension device so that a more accurate diagnosis could be made, even during the actual procedure itself. An overall representation of the pressure variation ranges with respect to the arm-trunk angle was also determined, seen in Fig. 3 to the left, giving an overall idea of what arm positions will give a maximum/minimum intra-articular pressure.

Since the distension device will be acquiring data from the pressure transducer connected to the syringe pump, it became necessary to focus our attention on just what information the device is picking up and transmitting to the operator. Since only the intra-articular pressure of the shoulder capsule is needed, it is necessary to create filters that will not only eliminate any background noise, but also NOT eliminate any desired signals necessary for the procedure. The question then shifts to just what type of filters are necessary (low pass, high pass, band stop, band pass, etc.) and what their cutoff frequencies should be so as to achieve both goals. A brief look into some of the techniques available for determining a proper cutoff frequency has yielded several approaches, including Winter’s Residuals method (Winters, 1990), the Jackson “Knee” Method (Jackson, 1979), Autocorrelation-based Techniques (Challis, 1999), along with the use of global polynomials and spline functions. Unfortunately, all of these methods require the use of data gathered from actual hydraulic distension procedures; therefore the most that is currently possible is to use whatever data will be gathered from the animal model testing once those have been completed.
Figure 3: Intra-articular Pressure vs. Arm-Trunk Angle for Type 1, 2, and 3 Rotator Cuff Tears (Left, Top to Bottom), Loose Shoulders, Rotator Interval Lesions, and Recurrent Anterior Dislocations (Right, Top to Bottom) (Hashimoto, et al., 1995)

Figure 4: Unstable shoulder groups. A, Loose shoulder...