Infrared Thermal Imaging as a Quantitative Tool for Pain Mapping and Range of Motion Outcomes in Total Knee Arthroplasty Patients

Aisha Suhaiba[1], Apurva Swapnil Choubey, Lucas Paladino, Abhishek Deshpande, Asher Eli Lichtig[2], Ye Lin, Julio Cesar Castillo Tafur, Mark H Gonzalez

[1]University of Illinois at Chicago College of Medicine, [2]University of Illinois Chicago

INTRODUCTION: Patients undergoing total knee arthroplasty (TKA) experience pain and limitations in range of motion (ROM) in the postoperative period. Prior research has shown that elevated skin temperatures may be observed in arthritic knees as a response to inflammation and increased blood flow. In existing literature, no link between skin surface temperature and patient-reported pain locations and outcomes has been established. This study aims to investigate the use of thermal imaging as an objective quantitative marker for tracking pain and ROM outcomes in patients before and after TKA.

METHODS: We prospectively enrolled 31 patients (20 female, 11 male) undergoing elective, unilateral TKA at an urban, tertiary care center. Exclusion criteria included ongoing pregnancy and severe trauma. Infrared cameras were used to capture anterior thermal images of the patients' knees preoperatively and at four follow-up visits. Patients completed diagrams *(Fig. 1)* to indicate their most severe areas of pain (AOP). The infrared camera's associated image analysis software was used to measure average and maximum skin surface temperatures (SST) from the thermal images. Rectangles were drawn over each knee and ellipses drawn over the AOP and its corresponding contralateral area *(Fig. 2)*. ΔSST is defined as the difference in temperature between the surgical and nonsurgical knee for a given region. One way ANOVA testing was used to compare temperatures between visits. ROM, SST, and postoperative day were compared using Pearson's correlation coefficient. Paired t-tests compared temperatures of surgical and nonsurgical knees.

RESULTS: There is a statistically significant negative correlation between ΔSST_{avg} and ROM (r = -0.337, p = 0.007) *(Fig. 3)*. Preoperatively, there was no significant difference between the AOP SST_{avg} and the nonsurgical global and regional controls nor between AOP SST_{avg} and the surgical knee global SST_{avg}. Postoperatively, AOP SST_{avg} was significantly greater than the nonsurgical global and regional controls (p < 0.001) and the surgical knee global SST_{avg} (p = 0.015). Average operative knee SSTs were significantly increased compared to nonsurgical knees at postoperative visit 1 (26 days; + 2.634°C; p < 0.001), visit 2 (43 days; + 2.5°C; p = 0.007), and visit 3 (91 days; + 2.7°C; p = 0.002). Postoperative day (POD) and ROM were significantly positively correlated (r = 0.324, p = 0.012) *(Fig. 4)*, but POD and ΔSST_{avg} were not significantly negatively correlated (r = -0.270, p = 0.058) *(Fig. 5)*.

DISCUSSION AND CONCLUSION:

Our data validate previous findings that SST increases following TKA, most likely due to increases in blood flow and inflammatory cytokines. The increase in nonsurgical knee SST post-procedure suggests that post-surgical inflammation is more global than expected. Most importantly, we have demonstrated an inverse relationship between SST and ROM. ROM is more strongly correlated with ΔSST than POD, suggesting that thermal imaging may provide means for a more reliable estimation of postoperative prognosis than simply time from surgery. While pain and its reporting are more subjective, postoperatively, thermal imaging can be used to identify likely areas of inflammation. Thermal imaging provides a minimal-risk, non-invasive, measurable data point that may allow patients to more easily track their functional recovery. This can further incentivize patients to adhere to regimens that reduce ΔSST–from existing regimens of anti-inflammatory medications to additional pharmaceutical and exercise protocols. Patients, physicians, and physical therapists all stand to benefit from the use of thermal imaging following TKA.

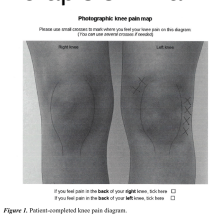

Figure 1. Patient-completed knee pain diagram.

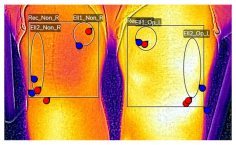

Figure 2. Image analysis on thermal image taken by infrared camera.

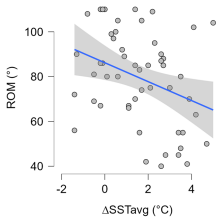

Figure 3. Difference in average skin surface temperature between operative and non-operative knees vs range of motion. Pearson's negative correlation coefficient r = -0.337, p = 0.007.

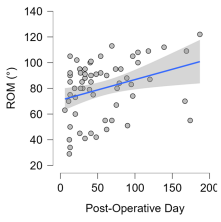

Figure 4. Range of motion over post-operative time. Pearson's positive correlation coefficient r = 0.324, p = 0.012.

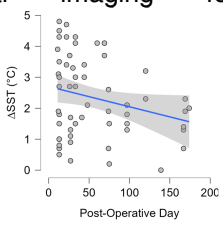

Figure 5. Difference in average skin surface temperature between operative and non-operative knees over post-operative time. Pearson's negative correlation coefficient r = -0.270, p = 0.058.