The Role of Infrared Thermal Imaging in Tracking Recovery Post-Total Knee Arthroplasty

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INTRODUCTION: Osteoarthritis (OA) is a degenerative disease of articular cartilage commonly affecting the knee, hip, and hand joints. Total knee arthroplasty (TKA), or knee replacement, is a procedure done in cases of severe knee OA. Patients undergoing TKA experience pain and limitations in range of motion (ROM) in the post-operative period. Prior research has shown that elevated skin temperatures may be observed in arthritic knees as a response to inflammation and increased blood flow.[1, 2] In existing literature, no link between skin surface temperature and patient reported pain locations and outcomes has been established. This study aims to build on our prior work linking skin surface temperature (SST) to ROM and investigate the use of thermal imaging as an objective quantitative marker for tracking pain outcomes in patients before and after TKA.

METHODS: Upon IRB approval, we obtained informed consent from and prospectively enrolled 31 patients (20 female, 11 male) undergoing elective, unilateral TKA at an urban, tertiary care center. A FLIR One infrared camera was used to capture anterior thermal images of the patients' knees pre-operatively and at four follow up visits. Patients completed diagrams to indicate their most severe areas of pain (AOP). The camera's associated image analysis software was used to measure average and maximum SST from the thermal images. Rectangles were drawn over each knee and ellipses drawn over the AOP and its corresponding contralateral area *(Fig. 1)*. ΔSST is defined as the difference in temperature between the operative and non-operative knee for a given region. One way ANOVA testing was used to compare temperatures between visits. ROM, SST, and post-operative day were compared using Pearson's correlation coefficient. Paired t-tests compared temperatures of operative and non-operative knees.

RESULTS: 94 measurements were obtained from 31 participants (20 female, 11 male). There is a statistically significant negative correlation between ΔSST_{avg} and ROM ($r = -0.337$, $p = 0.007$) *(Fig. 2)*. Pre-operatively, there was no significant difference between the AOP SST_{avg} and the non-operative global and regional controls nor between AOP SST_{avg} and the operative knee global SST_{avg}. Post-operatively, AOP SST_{avg} was significantly greater than the non-operative global and regional controls ($p < 0.001$) and the operative knee global SST_{avg} ($p = 0.015$). Average operative knee SSTs were significantly increased compared to non-operative knees at post-operative visit 1 (26 days; + 2.6°C; $p < 0.001$), visit 2 (43 days; + 2.5°C; $p = 0.007$), and visit 3 (91 days; + 2.7°C; $p = 0.002$). Post-operative day and ROM were significantly positively correlated ($r = 0.324$, $p = 0.012$) *(Fig. 3)*, but post-operative day and ΔSST_{avg} were not significantly negatively correlated ($r = -0.270$, $p = 0.058$).

DISCUSSION: Our data validate previous findings that SST increases following TKA, most likely due to increases in blood flow and inflammatory cytokines. The increase in non-operative knee SST post-procedure suggests that post-surgical inflammation is more global than expected. The presence of a statistically significant difference between the AOP and global operative knee SST post-operatively but not pre-operatively suggests that the pain patients experience post-operatively is specific to the procedure and can be tracked as a metric reflective of post-operative recovery. We confirmed our previous finding of an inverse relationship between SST and ROM. Importantly, ROM is more strongly correlated with ΔSST than POD, suggesting that thermal imaging may provide means for a more reliable estimation of post-operative prognosis than simply time from surgery. While pain and its reporting are more subjective, post-operatively, 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 tangibly understand 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.

SIGNIFICANCE/CLINICAL RELEVANCE: Given the subjectivity of patient-reported pain as an indicator of inflammation, thermal imaging can serve as a useful, objective clinical adjunct in the assessment of pre and post-surgical inflammation.

REFERENCES: [1] Windisch C et al. *Knee Surg Sports Traumatol Arthrosc* (2016). [2] Fokam D et al. *J Basic Clin Physiol Pharmacol* (2019).

IMAGES AND TABLES:

Figure 1. Image analysis on thermal image taken by infrared camera.

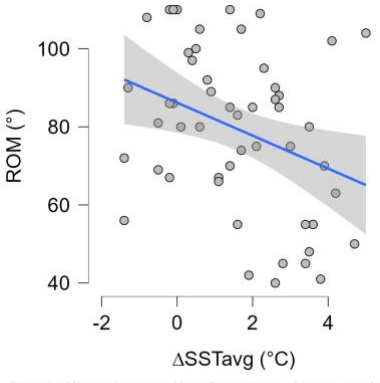

Figure 2. Difference in average skin surface temperature between operative and non-operative knees vs range of motion. Pearson's negative correlation coefficient r = -0.337, $p = 0.007$.

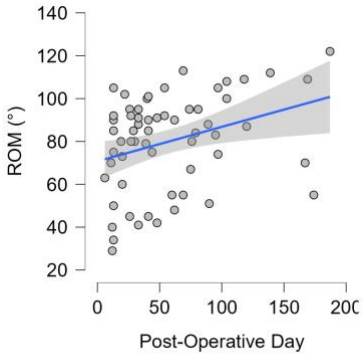

Figure 3. Range of motion over post-operative time. Pearson's positive correlation coefficient r = 0.324, $p = 0.012$.