**APPENDIX A**

**Figure 1.** Flow chart of patient enrollment and exclusion in this supplementary analysis.



**Figure 2.** Left ventricular bullseye plots for regional segmental changes from pre-surgical to post-surgical myocardial strain values in patients undergoing combined cardiac surgery (CABG + other valvular surgery). The outer ring represents basal segments, the middle ring represents the mid-papillary segments, and the inner ring represents the apical segments. The last circle represents the true apex. Values in each segment represent the raw mean difference from pre- to postoperative strain values, with standard deviations in parentheses. Shaded areas represent statistically significant decreases in function from pre- to post-surgery (p<0.05). CABG = coronary artery bypass graft.

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**APPENDIX B**

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| **Table 1. Segmental Strain Values and Scoring System** |
|  |  Segment Classification and Score |
|  | **Normal (0)** | **Mild-to-moderate (-1)** | **Severe (-2)** |
| Strain Measure  |  |  |  |
| Area | <-25 | -19 to -24 | >-18 |
| Longitudinal | <-12 | -10 to -11 | >-9 |
| Circumferential | <-16 | -12 to -15 | >-11 |
| Radial | <35 | 25 to 34 | >24 |
| Each of the 17 segments were scored using the following thresholds[[1]](#footnote-2). Then, each patient had their scores for area, longitudinal, circumferential, and radial strain summed up for each of the 17 segments for pre-cardiac surgery, post-cardiac surgery, and for the differences between pre- and post. For example, the highest possible score for a particular patient (pre- or post-) would be 0 (all normal function), and the lowest possible score would be -34 (all severe dysfunction).  |

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| **Table 2. Measures of regional LV function pre- and post-aortic valve replacement** |
|  | **Area Strain** | **Circumferential Strain** | **Longitudinal Strain** | **Radial Strain** |
|  | **Pre** | **Post** | **Pre**  | **Post** | **Pre** | **Post** | **Pre** | **Post** |
| Global Strain[[2]](#footnote-3) |  |  |  |  |  |  |  |  |
| **AVR** | -22.29 (7.36) | -16.98 (5.72) | -14.99 (4.68) | -10.43 (4.47) | -10.49 (4.38) | -8.91 (3.36) | 34.92 (14.28) | 24.49 (9.53) |
| Segmental Strain |  |  |  |  |  |  |  |  |
| **AVR** |  |  |  |  |  |  |  |  |
| **Basal anterior** | -20.24 (11.78) | -16.54 (10.40) | -16.02 (7.94) | -12.92 (7.07) | -8.54 (8.86) | -7.69 (6.47) | 29.55 (20.08) | 22.77 (16.56) |
| **Basal anteroseptal** | -17.47 (9.25) | -16.34 (9.01) | -14.63 (6.18) | -11.05 (5.57) | -7.39 (5.29) | -8.77 (6.41) | 23.74 (14.75) | 21.75 (13.80) |
| **Basal inferoseptal** | -18.42 (9.59) | -19.06 (7.57) | -12.26 (6.07) | -11.34 (4.65) | -10.05 (6.37) | -11.46 (5.73) | 24.93 (14.60) | 25.33 (11.60) |
| **Basal inferior** | -16.94 (10.92) | -14.07 (8.85) | -11.12 (7.94) | -8.90 (6.93) | -9.37 (7.65) | -8.11 (6.37) | 23.73 (17.99) | 18.95 (12.26) |
| **Basal inferolateral** | -12.92 (8.90) | -14.04 (9.84) | -11.31 (5.23) | -10.54 (5.83) | -6.45 (7.12) | -6.65 (8.54) | 17.59 (12.05) | 18.95 (15.43) |
| **Basal anterolateral** | -16.83 (10.49) | -17.31 (10.79) | -14.28 (6.06) | -14.52 (7.13) | -6.75 (7.03) | -6.97 (6.94) | 24.07 (17.81) | 26.03 (16.03) |
| **Mid anterior** | -23.22 (14.57) | -16.62 (8.80) | -17.47 (9.47) | -10.88 (6.65) | -9.49 (8.39) | -8.62 (7.07) | 35.41 (28.96) | 22.04 (13.91) |
| **Mid anteroseptal** | -26.48 (12.62) | -21.45 (11.41) | -17.43 (7.65) | -11.55 (7.19) | -13.40 (8.70) | -13.21 (7.30) | 41.49 (27.23) | 30.68 (19.76) |
| **Mid inferoseptal** | -28.06 (7.95) | -25.54 (10.24) | -16.13 (5.88) | -12.70 (7.01) | -16.71 (5.70) | -17.09 (6.91) | 41.42 (14.78) | 37.35 (18.93) |
| **Mid inferior** | -25.81 (9.92) | -19.09 (9.90) | -15.05 (7.40) | -9.41 (7.40) | -14.66 (6.46) | -13.53 (6.22) | 38.32 (18.36) | 26.40 (16.25) |
| **Mid inferolateral** | -21.81 (10.51) | -15.94 (9.58) | -13.86 (5.96) | -11.00 (6.08) | -11.36 (7.88) | -7.79 (7.33) | 31.49 (18.89) | 21.36 (14.16) |
| **Mid anterolateral** | -22.03 (11.49) | -18.70 (10.07) | -16.97 (6.09) | -15.16 (6.52) | -9.89 (7.94) | -7.43 (6.99) | 33.22 (20.57) | 26.49 (16.94) |
| **Apical anterior** | -20.88 (14.14) | -14.32 (7.30)  | -15.32 (9.54) | -9.30 (7.04) | -8.83 (7.25) | -7.91 (4.08) | 33.51 (27.47) | 19.57 (11.24) |
| **Apical septal** | -30.43 (11.53) | -21.06 (12.28) | -17.68 (8.20) | -13.03 (8.90) | -18.20 (6.66) | -12.09 (6.75) | 50.32 (23.82) | 31.16 (21.97) |
| **Apical inferior** | -32.98 (11.82) | -20.80 (11.33) | -17.86 (9.40) | -10.79 (7.59) | -20.00 (6.11) | -14.03 (6.10) | 57.92 (28.81) | 30.81 (20.40) |
| **Apical lateral** | -27.13 (9.67) | -21.62 (9.97) | -18.32 (6.23) | -13.85 (7.18) | -12.90 (6.62) | -10.80 (5.16) | 43.30 (20.36) | 32.84 (18.41) |
| **Apex** | -26.84 (14.21) | -14.82 (10.48) | -16.65 (9.56) | -8.95 (6.48) | -16.69 (8.01) | -9.90 (6.49) | 56.09 (34.29) | 28.43 (22.75) |

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| **Table 3. Measures of regional LV function pre- and post-mitral valve repair or replacement** |
|  | **Area Strain** | **Circumferential Strain** | **Longitudinal Strain** | **Radial Strain** |
|  | **Pre** | **Post** | **Pre**  | **Post** | **Pre** | **Post** | **Pre** | **Post** |
| Global Strain[[3]](#footnote-4) |  |  |  |  |  |  |  |  |
| **MVR** | -30.08 (7.45) | -19.77 (6.87) | -19.41 (4.13) | -11.98 (4.68) | -15.33 (5.58) | -10.56 (4.12) | 51.39 (16.89) | 29.34 (12.10) |
| Segmental Strain |  |  |  |  |  |  |  |  |
| **MVR** |  |  |  |  |  |  |  |  |
| **Basal anterior** | -28.29 (13.83) | -18.72 (10.81) | -20.95 (8.22) | -13.04 (7.85) | -13.20 (9.88) | -9.57 (6.96) | 46.76 (29.96) | 26.69 (19.58) |
| **Basal anteroseptal** | -25.33 (11.90) | -18.50 (9.90) | -19.86 (6.96) | -13.84 (6.30) | -10.47 (8.84) | -8.21 (6.14) | 39.37 (24.12) | 25.48 (16.23) |
| **Basal inferoseptal** | -24.89 (9.67) | -20.90 (9.09) | -16.54 (6.88) | -13.28 (6.60) | -12.42 (7.42) | -11.74 (5.83) | 36.70 (18.31) | 28.94 (15.17) |
| **Basal inferior** | -23.53 (10.08) | -15.68 (10.31) | -16.62 (6.45) | -9.20 (6.84) | -11.04 (7.59) | -10.09 (7.15) | 35.21 (18.84) | 21.37 (15.22) |
| **Basal inferolateral** | -17.93 (12.06) | -17.33 (9.56) | -12.97 (6.90) | -11.97 (6.58) | -9.69 (9.18) | -9.33 (7.24) | 25.61 (19.13) | 24.22 (15.77) |
| **Basal anterolateral** | -24.86 (12.14) | -22.48 (9.52) | -17.49 (7.30) | -15.37 (7.33) | -13.11 (9.32) | -10.91 (7.63) | 40.92 (24.67) | 33.87 (17.56) |
| **Mid anterior** | -35.13 (12.55) | -20.40 (11.06) | -23.51 (7.00) | -11.53 (7.41) | -17.32 (9.81) | -11.50 (8.08) | 60.77 (29.48) | 29.01 (19.11) |
| **Mid anteroseptal** | -35.37 (12.72) | -25.05 (12.88) | -22.94 (7.42) | -13.34 (7.76) | -18.52 (8.60) | -15.43 (8.52) | 61.83 (31.74) | 38.39 (25.46) |
| **Mid inferoseptal** | -34.14 (9.06) | -27.67 (10.18) | -20.28 (5.93) | -13.97 (7.89) | -19.50 (7.32) | -18.10 (6.80) | 56.21 (19.87) | 41.78 (21.01) |
| **Mid inferior** | -34.18 (11.81) | -22.64 (10.17) | -22.01 (7.41) | -12.28 (6.03) | -17.76 (8.30) | -13.79 (7.15) | 59.00 (27.32) | 32.45 (18.07) |
| **Mid inferolateral** | -27.49 (11.13) | -19.47 (10.84) | -16.71 (6.21) | -12.96 (6.72) | -14.94 (9.44) | -9.40 (7.61) | 42.34 (21.90) | 27.78 (18.23) |
| **Mid anterolateral** | -28.34 (12.97) | -21.36 (10.16) | -19.70 (7.59) | -14.68 (7.37) | -13.79 (10.56) | -10.28 (6.92) | 47.59 (28.71) | 31.13 (18.12) |
| **Apical anterior** | -29.10 (12.49) | -14.98 (9.63) | -19.38 (7.72) | -8.82 (6.55) | -14.29 (7.71) | -8.48 (6.28) | 47.56 (26.11) | 20.95 (16.46) |
| **Apical septal** | -39.21 (9.22) | -22.41 (12.80) | -22.24 (6.52) | -13.67 (9.10) | -23.89 (6.77) | -12.82 (6.78) | 71.57 (26.23) | 34.17 (24.81) |
| **Apical inferior** | -38.94 (10.97) | -25.37 (11.02) | -22.12 (7.76) | -13.81 (7.38) | -23.23 (7.20) | -15.28 (6.92) | 73.94 (28.36) | 39.13 (21.64) |
| **Apical lateral** | -30.01 (12.93) | -21.87 (12.21) | -19.79 (9.60) | -14.30 (8.62) | -15.50 (7.11) | -11.35 (7.56) | 51.92 (26.29) | 33.66 (22.70) |
| **Apex** | -29.30 (10.76) | -15.16 (9.70) | -16.92 (7.64) | -9.84 (6.35) | -18.95 (6.16) | -9.44 (6.07) | 58.23 (28.21) | 28.73 (19.20) |

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| **Table 4. Measures of regional LV function pre- and post-coronary artery bypass graft** |
|  | **Area Strain** | **Circumferential Strain** | **Longitudinal Strain** | **Radial Strain** |
|  | **Pre** | **Post** | **Pre**  | **Post** | **Pre** | **Post** | **Pre** | **Post** |
| Global Strain[[4]](#footnote-5) |  |  |  |  |  |  |  |  |
| **CABG** | -23.82 (5.95) | -16.85 (6.68) | -15.60 (3.89) | -10.79 (4.51) | -11.66 (3.83) | -8.47 (3.60) | 36.82 (12.20) | 23.71 (10.80) |
| Segmental Strain |  |  |  |  |  |  |  |  |
| **CABG** |  |  |  |  |  |  |  |  |
| **Basal anterior** | -22.66 (9.11) | -15.08 (9.07) | -15.98 (6.65) | -10.94 (7.20) | -11.68 (7.54) | -7.74 (5.44) | 32.27 (15.92) | 20.24 (14.14) |
| **Basal anteroseptal** | -19.88 (10.08) | -16.11 (9.84) | -16.30 (6.73) | -11.84 (6.85) | -8.29 (6.77) | -7.92 (5.96) | 27.87 (16.91) | 21.93 (14.12) |
| **Basal inferoseptal** | -20.43 (8.97) | -19.17 (8.40) | -14.78 (6.73) | -12.25 (5.90) | -10.50 (5.27) | -10.33 (5.72) | 27.97 (14.68) | 25.86 (12.54) |
| **Basal inferior** | -17.92 (8.95) | -15.88 (8.92) | -12.32 (6.71) | -9.52 (5.56) | -9.27 (6.17) | -9.17 (6.86) | 24.26 (14.04) | 20.95 (13.19) |
| **Basal inferolateral** | -16.35 (9.50) | -15.34 (8.52) | -12.41 (5.51) | -11.02 (5.62) | -8.44 (6.62) | -7.75 (6.30) | 22.09 (14.55) | 20.43 (12.79) |
| **Basal anterolateral** | -18.65 (8.92) | -18.14 (9.35) | -15.31 (5.62) | -13.77 (6.94) | -8.82 (7.01) | -8.38 (6.03) | 27.38 (14.88) | 25.83 (14.84) |
| **Mid anterior** | -24.59 (12.23) | -14.72 (10.23) | -17.89 (7.73) | -9.68 (6.73) | -10.80 (7.88) | -7.80 (5.97) | 37.26 (23.62) | 19.88 (16.53) |
| **Mid anteroseptal** | -27.47 (12.15) | -18.41 (11.15) | -18.29 (8.17) | -11.05 (6.93) | -13.65 (7.53) | -10.26 (6.59) | 43.01 (25.39) | 26.12 (18.06) |
| **Mid inferoseptal** | -28.16 (7.44) | -25.09 (9.71) | -16.47 (5.73) | -12.93 (7.15) | -17.02 (5.21) | -16.80 (5.54) | 41.50 (14.89) | 36.08 (17.19) |
| **Mid inferior** | -26.19 (8.39) | -19.65 (7.96) | -15.18 (6.05) | -10.15 (5.81) | -14.60 (6.18) | -13.16 (5.86) | 38.62 (16.15) | 26.55 (12.64) |
| **Mid inferolateral** | -23.11 (8.55) | -17.39 (10.71) | -15.25 (4.72) | -12.78 (6.53) | -11.41 (6.98) | -7.73 (6.97) | 32.70 (16.18) | 24.16 (16.49) |
| **Mid anterolateral** | -24.77 (8.93) | -20.31 (10.32) | -18.86 (5.30) | -16.20 (7.81) | -10.46 (7.38) | -7.36 (6.93) | 36.92 (18.82) | 29.01 (17.67) |
| **Apical anterior** | -22.40 (14.36) | -11.90 (10.53) | -15.57 (9.48) | -8.14 (7.15) | -10.23 (7.78) | -5.94 (5.43) | 35.35 (28.20) | 16.36 (16.18) |
| **Apical septal** | -30.38 (11.84) | -16.81 (12.23) | -16.23 (8.24) | -10.15 (8.09) | -19.38 (6.95) | -9.76 (6.44) | 50.50 (27.15) | 24.67 (20.31) |
| **Apical inferior** | -33.46 (9.78) | -22.84 (9.51) | -17.80 (7.46) | -12.90 (5.81) | -20.58 (5.94) | -13.44 (6.89) | 56.54 (23.47) | 33.30 (17.14) |
| **Apical lateral** | -29.07 (9.83) | -23.70 (10.30) | -19.11 (7.91) | -15.48 (8.29) | -14.13 (5.96) | -11.26 (6.14) | 46.78 (20.35) | 35.93 (19.62) |
| **Apex** | -25.13 (13.15) | -13.77 (11.57) | -15.07 (8.42) | -8.77 (7.33) | -16.00 (7.40) | -8.68 (6.92) | 49.53 (33.48) | 27.25 (23.74) |

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| **Table 5. Measures of regional LV function pre- and post-combined cardiac surgery** |
|  | **Area Strain** | **Circumferential Strain** | **Longitudinal Strain** | **Radial Strain** |
|  | **Pre** | **Post** | **Pre**  | **Post** | **Pre** | **Post** | **Pre** | **Post** |
| Global Strain[[5]](#footnote-6) |  |  |  |  |  |  |  |  |
| **Combined** | -26.55 (7.13) | -15.63 (6.15) | -16.62 (5.02) | -8.85 (4.57) | -13.60 (4.27) | -9.07 (3.95) | 41.66 (13.31) | 22.25 (9.84) |
| Segmental Strain |  |  |  |  |  |  |  |  |
| **Combined** |  |  |  |  |  |  |  |  |
| **Basal anterior** | -26.41 (10.64) | -15.38 (11.75) | -19.04 (7.08) | -9.75 (8.58) | -11.54 (7.68) | -8.85 (6.49) | 40.07 (22.08) | 21.35 (18.06) |
| **Basal anteroseptal** | -23.31 (11.57) | -18.44 (10.55) | -16.04 (7.87) | -10.24 (7.21) | -11.38 (7.85) | -11.81 (5.77) | 34.15 (19.31) | 26.31 (17.42) |
| **Basal inferoseptal** | -21.92 (8.70) | -16.28 (7.89) | -13.95 (5.81) | -10.16 (5.82) | -12.17 (7.52) | -9.48 (5.52) | 31.09 (15.32) | 21.20 (11.86) |
| **Basal inferior** | -22.54 (11.34) | -11.24 (8.75) | -14.77 (7.28) | -7.52 (6.50) | -11.27 (8.50) | -6.46 (5.31) | 33.48 (19.96) | 12.99 (10.33) |
| **Basal inferolateral** | -18.44 (10.33) | -14.17 (10.29) | -12.85 (6.33) | -9.87 (6.41) | -9.31 (7.76) | -7.17 (6.92) | 25.57 (15.23) | 19.23 (15.34) |
| **Basal anterolateral** | -22.67 (9.03) | -18.77 (9.96) | -17.12 (6.17) | -16.27 (7.05) | -9.66 (7.51) | -6.92 (6.73) | 34.20 (15.91) | 28.37 (16.46) |
| **Mid anterior** | -30.82 (11.80) | -16.74 (10.00) | -19.80 (8.36) | -9.57 (6.03) | -15.44 (7.50) | -9.57 (7.04) | 48.83 (22.63) | 22.64 (15.61) |
| **Mid anteroseptal** | -30.26 (11.40) | -19.99 (10.92) | -18.64 (7.43) | -9.31 (6.53) | -15.99 (7.57) | -13.81 (7.78) | 47.85 (23.19) | 28.03 (19.62) |
| **Mid inferoseptal** | -29.95 (8.10) | -23.15 (9.32) | -16.51 (6.32) | -10.37 (6.19) | -18.42 (5.97) | -17.56 (7.37) | 45.47 (17.55) | 30.93 (18.16) |
| **Mid inferior** | -31.27 (9.42) | -18.07 (6.81) | -18.58 (7.66) | -7.79 (5.24) | -17.66 (5.98) | -14.45 (6.23) | 49.55 (21.51) | 22.95 (10.86) |
| **Mid inferolateral** | -26.03 (8.20) | -18.30 (9.03) | -14.92 (4.59) | -10.40 (6.33) | -14.48 (6.91) | -10.87 (7.04) | 37.55 (13.97) | 24.56 (15.19) |
| **Mid anterolateral** | -28.60 (11.04) | -20.02 (8.08) | -18.58 (7.84) | -14.75 (7.27) | -14.63 (7.45) | -8.07 (5.77) | 45.40 (21.97) | 26.67 (14.38) |
| **Apical anterior** | -21.59 (11.43) | -12.01 (8.57) | -14.60 (7.65) | -7.66 (6.12) | -10.26 (6.53) | -7.40 (5.30) | 31.99 (20.21) | 16.19 (12.99) |
| **Apical septal** | -30.45 (10.46) | -14.44 (7.16) | -17.47 (8.65) | -8.57 (7.11) | -17.95 (5.95) | -9.24 (5.84) | 48.66 (21.93) | 18.74 (11.02) |
| **Apical inferior** | -33.47 (9.88) | -21.55 (9.40) | -18.34 (6.82) | -10.83 (6.87) | -20.40 (6.06) | -14.51 (5.61) | 56.55 (24.64) | 30.98 (16.77) |
| **Apical lateral** | -30.75 (12.58) | -22.32 (10.50) | -19.75 (10.19) | -13.43 (7.66) | -16.08 (5.96) | -12.05 (5.41) | 51.76 (26.44) | 33.18 (18.84) |
| **Apex** | -23.26 (13.49) | -11.18 (7.69) | -14.67 (8.53) | -6.78 (4.70) | -13.81 (7.87) | -8.33 (5.67) | 43.55 (28.15) | 21.61 (13.87) |

1. Howard-Quijano K, Salem A, Barkulis C, et al. Preoperative Three-Dimensional Strain Imaging Identifies Reduction in Left Ventricular Function and Predicts Outcomes After Cardiac Surgery. *Anesth Analg.* 2017;124(2):419-428. [↑](#footnote-ref-2)
2. Howard-Quijano K, Salem A, Barkulis C, et al. Preoperative Three-Dimensional Strain Imaging Identifies Reduction in Left Ventricular Function and Predicts Outcomes After Cardiac Surgery. *Anesth Analg.* 2017;124(2):419-428. [↑](#footnote-ref-3)
3. Howard-Quijano K, Salem A, Barkulis C, et al. Preoperative Three-Dimensional Strain Imaging Identifies Reduction in Left Ventricular Function and Predicts Outcomes After Cardiac Surgery. *Anesth Analg.* 2017;124(2):419-428. [↑](#footnote-ref-4)
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5. Howard-Quijano K, Salem A, Barkulis C, et al. Preoperative Three-Dimensional Strain Imaging Identifies Reduction in Left Ventricular Function and Predicts Outcomes After Cardiac Surgery. *Anesth Analg.* 2017;124(2):419-428. [↑](#footnote-ref-6)