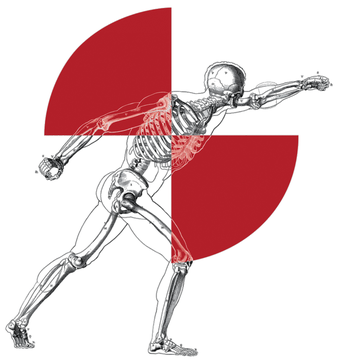

Intracortical Porosity of the Distal Radius: Association with Evidence of Systemic Remodeling

Randee L. Hunter, Amanda M. Agnew

Skeletal Biology Research Laboratory, The Ohio State University

INTRODUCTION

- Distal radius fractures are a common ailment following trauma whether during growth, at peak bone mass, or as a result of decreasing bone quality. Assessment of the integrity of cortical bone in the distal third of the radius has been used to inform fragility and fracture risk in the aging human population.

- Bone quality and its ability to adapt and resist gross fracture is multi-faceted and diminished in advancing age. Determining factors of bone quality include mass, microarchitecture, material properties of the extracellular matrix, microdamage accumulation, osteocyte density and remodeling rate (Burr 2014, Burr and Akkus 2014). Skeletal fragility increases under remodeling rates that are outside the physiological parameters to maintain healthy bone. Intracortical porosity is responsible for the decrease in bone mass, a key determinant of bone strength (Cho et al. 2006). Age related bone loss compromises strength by decreasing mass and adversely affecting microstructural quality parameters including a reduced ability to resist propagation and accumulation of microcracks (Seeman 2007, Seeman and Delmas 2006).

- Previous studies have found intracortical porosity increases with age in the cortical bone of the distal radius with concordant decreases in measures of mechanical integrity (Burghart et al. 2010, Macdonald et al. 2011). However, to assess the systemic changes in rate of bone turnover with age, the intracortical porosity of the clinically relevant radius should be compared to the same parameter in the rib. The rib maintains a relatively constant mechanical environment throughout life as inhalation and exhalation persist (Bellemare et al. 2003) and represents systemic and metabolic changes within the skeletal system (Robling and Stout 2003).

- The objective of this project is to explore the relationship between intracortical porosity and age in the rib, a measure of systemic bone turnover, and the distal cortex of the radius, an important clinical site for skeletal fragility and fracture risk. Additionally, the intra-individual relationship of age related bone loss between the anatomical sites is tested.

MATERIALS AND METHODS

- Skeletal samples from both the distal third of the cortex of the radius and the midshaft 6th rib were obtained from 15 male cadavers ranging in age from 49 to 100 years old. Undecalcified transverse thin sections were prepared using standard histological procedures and subsequently imaged under bright field light.

- Using ImageJ software, the following variables were measured and calculated (see Figure 1).
  - Total subperiosteal area (Tt.Ar) in mm^2: total cross sectional area
  - Total cortical area (Ct.Ar) in mm^2: area between periosteal and endosteal borders
  - Porosity area (Po.Ar) in mm^2: total area of all pores located within the Ct.Ar (excluding osteocytic lacunae)
  - Bone area (B.Ar) in mm^2: (Ct.Ar-Po.Ar) amount of bone within the cortex
  - Percent porosity (%Po.Ar): (Po.Ar/Ct.Ar) area of intracortical porosity relative to cortical area
  - Percent bone area (%B.Ar): (B.Ar/Tt.Ar) area of cortical bone removing the effects of porosity and normalizing by size

- Pearson correlations were computed for %B.Ar for the rib and the radius to establish the relationship between elements as well as to assess changes in intracortical porosity (%Po.Ar) occurring with age within each element. Lastly, correlations were performed to investigate the intra-individual relationship of %Po.Ar in the rib and radius.

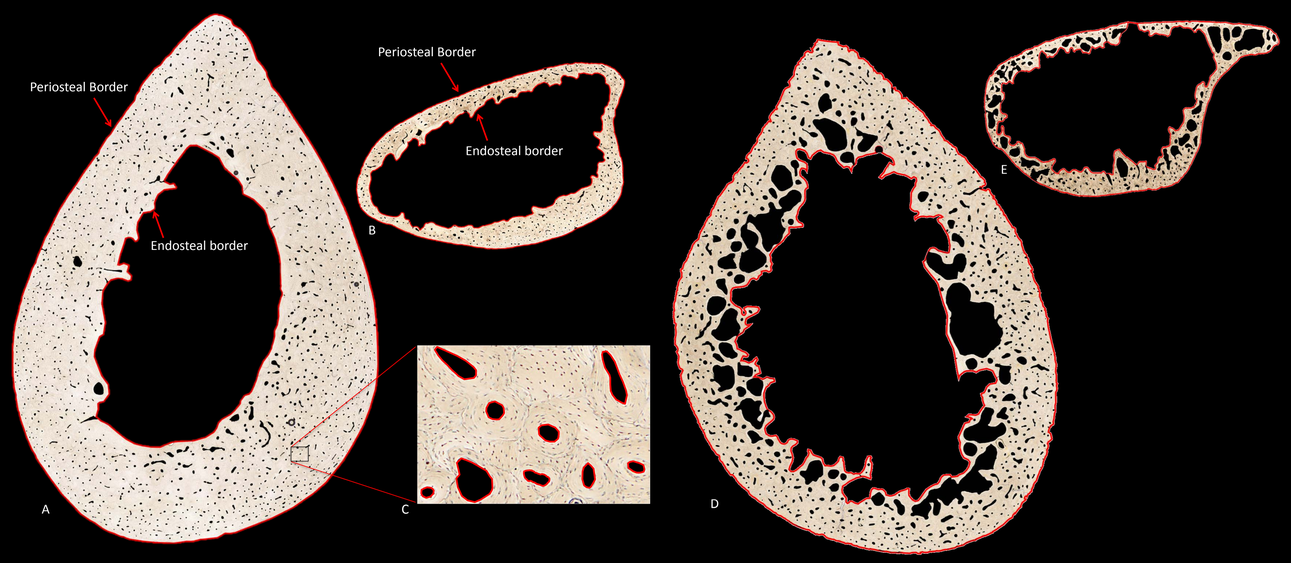

Figure 1: A) Distal radius cross section of 49 year old male demonstrating the periosteal and endosteal borders circumscribing the Ct.Ar. B) Corresponding midshaft rib section from the individual in 'A' representing the youngest of the sample. C) inset showing the measurement of Po.Ar for each section (black pores traced in red). D) Distal radius cross section of the oldest individual in the sample (100 years old) and E) Corresponding rib for 'D'. Note the inter-individual visual increase in porosity for both elements between the youngest and oldest individuals in this sample.

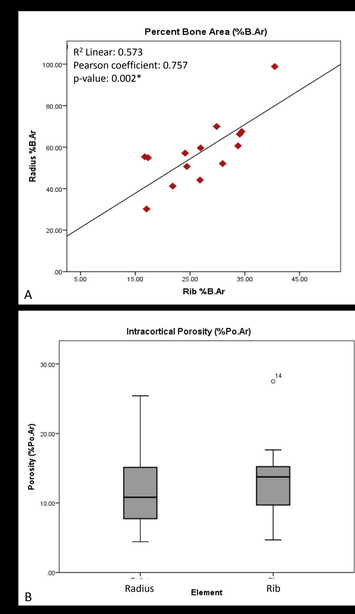

Figure 2: A) Relationship between rib and radius %B.Ar supporting the further comparison of microstructures contributing to these elements. B) %Po.Ar of radius and rib

RESULTS AND DISCUSSION

- %B.Ar between the elements is strongly correlated (Pearson coefficient: 0.757; p-value; 0.002) (Figure 2A). Intracortical porosity (%Po.Ar) is slightly higher in the rib (p-value= 0.076). Intracortical porosity in the radius has a stronger positive correlation with age than the rib though both are significantly correlated (Table 1). As previously reported, %Po.Ar in the radius increases more severely with age than in rib, supporting the effects of mechanical variability in the forearm over the thorax (Figure 3).

- %Po.Ar are strongly correlated in the radius and rib (Table 1 and Figure 4). Although the mechanical environment varies between elements, the systemic and metabolic influences experienced by the rib likely affect the cortical bone of the distal radius as well. As age related bone loss increases with age, this systemic trend is demonstrated within this sample as a linear relationship between the thorax and the clinically relevant radius of the forearm.

Rib %Po.Ar	Age (yrs)	Radius %Po.Ar
Pearson correlation coefficient	0.628	0.774
P-value	0.016*	0.001*
Radius %Po.Ar	**Age (yrs)**	**Radius %Po.Ar**
Pearson correlation coefficient	0.793	0.774
P-value	0.000*	0.001*

Table 1: Correlation coefficients and p-values for %Po.Ar and age in years and between rib and radius %Po.Ar. Both elements are significantly correlated with age. The radius shows a stronger correlation with age than the rib with a 0.793 correlation coefficient significant at the p=0.01 level. Intracortical porosity is significantly correlated at the p=0.001 level between the radius and the rib.

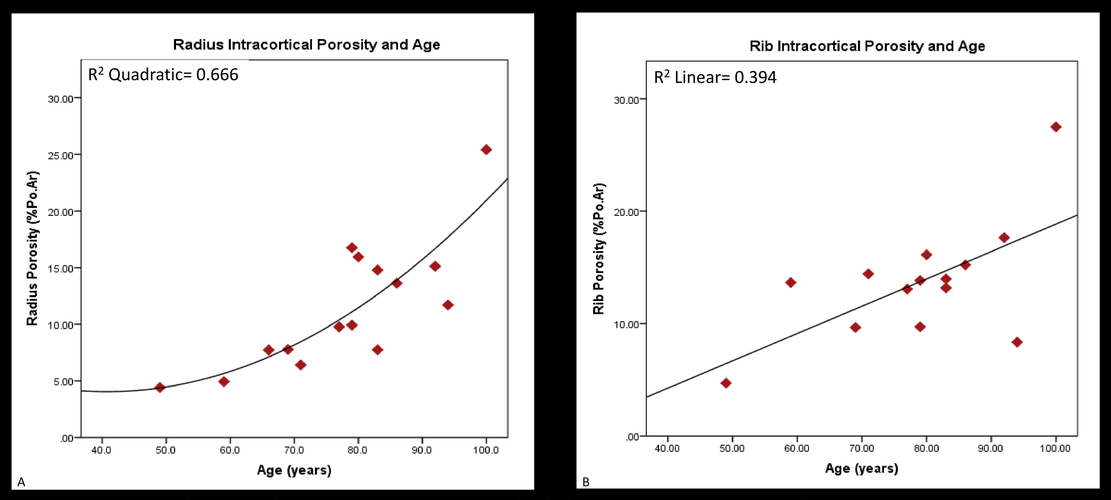

Figure 3: A) %Po.Ar increasing with age in the radius B) %Po.Ar increasing with age in the rib (See Table 1 for p-values)

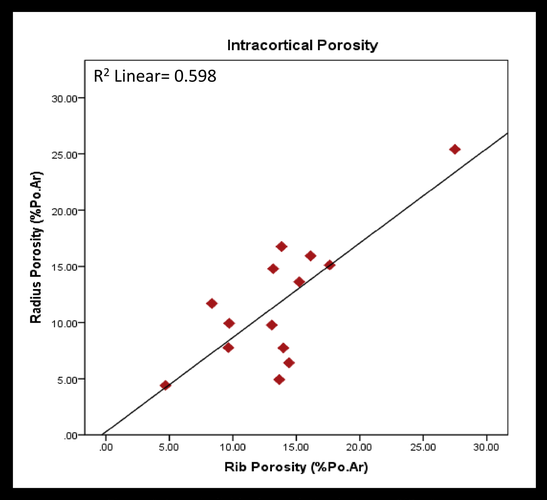

Figure 4: Intra-individual correlation between %Po.Ar

CONCLUSIONS

- In determining bone quality to assess skeletal fragility, the amount of intracortical porosity is crucial to prevention of fracture. As a component of bone mass and resistance to microdamage accumulation, the %Po.Ar in Figure 1A and 1B contributes to higher bone quality and presumably greater strength compared to the elements from a 100 year old represented in Figure 1D and 1E.

- This study demonstrates that despite the likely continued movement of the forearm with age (pronation at the distal radius), systemic and metabolic factors contribute to age related bone loss and fragility in the distal radius.

- Future research will include the addition of females and of a load bearing midshaft section of the femur to further compare intra-individual porosity.

CONTACT INFORMATION

Hunter.506@osu.edu

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