

Science and Technology Group Annual Report FY2022

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1 Introduction

Cellular wounding and repair of local plasma membranes occurs constantly in our bodies. Plasma membrane damage (PMD) can be induced by various triggers ranging from physical disruption and pathogen invasion to physiological cellular activities, such as muscle contraction, cell division, and the secretion of vesicles. Accumulating evidence suggests the involvement of cellular wound healing in various diseases. However, the detailed physiological consequences of plasma membrane repair are poorly understood. We recently discovered that plasma membrane damage activates a cell cycle checkpoint in yeast, resulting in cell cycle arrest during plasma membrane repair (Kono et al., Proc. Natl. Acad. Sci. U. S. A., 2016).

Furthermore, we also found that the plasma membrane damage induces permanent cell cycle arrest and senescent phenotypes in the cultured mammalian cell. Permanent cell cycle arrest is characterized by its specific metabolic activity and dramatic changes in cell morphology. Originally, it was proposed to be due to the shortening of telomeres after the repeated proliferation. Now that it is known that the cell cycle arrest is also induced by DNA damage response (DDR), oncogene expressions and several stresses. In addition to them, I am trying to show that the plasma membrane damage also triggers cellular senescence.

2 Activities and Findings

Using budding yeast and normal human fibroblasts, we show that cellular senescence, irreversible cell cycle arrest contributing to organismal aging, is the long-term outcome of PMD. To identify the genes essential for PMD response, we developed a simple PMD-damaging assay using a detergent and performed a systematic yeast genome-wide screen. The top hits in the screen are the endosomal sorting complexes required for transport (ESCRT) genes, encoding the well-described plasma membrane repair proteins in eukaryotes. Unexpectedly, the replicative lifespan regulator genes are enriched in our 48 hits. This finding suggests a close genetic association between the PMD response and the replicative lifespan regulations. Indeed, we show that PMD limits the replicative lifespan in budding yeast; the ESCRT activator AAA-ATPase VPS4-overexpression extends it. These results suggest that PMD limits replicative lifespan in budding yeast. Moreover, in normal human fibroblasts, we find that PMD induces premature senescence via the Ca²⁺-p53 axis but not the major senescence pathway, ATM/ATR pathway. Consistent with the results in yeast, transient overexpression of ESCRT-III, CHMP4B, suppressed the PMD-dependent senescence in normal human fibroblasts. Our study proposes that PMD limits cellular lifespan in two different eukaryotic cell types and highlights an underappreciated but ubiquitous senescent cell subtype, namely PMD-dependent senescent cells.

Senescent cells exhibit the senescence-associated secretory phenotype (SASP), a pathological feature that contributes to organismal aging. We previously showed that transient plasma membrane damage (PMD) induces a novel subtype of cellular senescence (PMDS) accompanied by SASP, but the overall expression profiles of SASP during PMDS induction was unknown. Using mRNA-seq, qPCR, and bioinformatics, we revealed the time-resolved SASP transcriptomic profile in PMDS in comparison with calcium influx-induced senescence, DNA damage response-induced senescence, and replicative senescence. SASP is diverse at early senescence and becomes relatively uniform at late senescence among the different senescence triggers. Diverse SASP may contribute to senescent cell subtype-specific paracrine/autocrine functions in vivo. These works were open to public in the bioArxiv, and already submitted to the journals.

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3 Collaborations

Prof. Keiko Kono, Nurhanani Binti Razali, Kojiro Suda, Yatzu Chiu (Kono Unit, OIST)
Dr. Takeshi Maruyama (Waseda University)
Prof. Nobuo Noda (Hokkaido University)
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4 Publications and other output

(bioRxiv) Suda K#, Moriyama Y#, Masukagami Y, Razali N, Chiu Y, Nishimura K, Barbee H, Takase H, Sugiyama S, Sato Y, Higashiyama T, Johmura Y, Nakanishi M, Kono K*. (#these authors contributed equally)

"Plasma membrane damage limits replicative lifespan in yeast and induces premature senescence in human fibroblasts" (in revision)

<https://www.biorxiv.org/content/10.1101/2021.03.26.437120v3>

(bioRxiv) Razali N, Moriyama Y, Chiu Y, Suda K, Kono K*.

Time-resolved transcriptomic profiling of senescence-associated secretory phenotype (SASP) in multiple senescent cell subtypes.

<https://www.biorxiv.org/content/10.1101/2022.06.27.497690v1>

International conference

○Moriyama Y and Kono K*. (2022 Oct)

"Plasma membrane damage, immune response, and cellular senescence" The 28th East Asia Joint Symposium on biomedical Research, Shanghai Tech University, China and Zoom. Invited talk.

Barbee H, Moriyama Y, and Kono K*.

"Plasma membrane damage-induced senescent cells accelerate wound healing via extracellular vesicles and soluble molecules" (2022 Dec) Cell Bio 2022 (ASCB/EMBO meeting), Washington DC, USA. Poster.

Suda K, Moriyama Y, Razali N, Chiu Y, and Kono K*.

"Plasma membrane damage limits replicative lifespan in yeast and induces premature senescence in human fibroblasts" (2022 Oct) EMBO Workshop 2022 The DNA damage response, immunity and aging, Singapore. Poster.

Razali N, Moriyama Y, Chiu Y, Suda K, Turkki T and Kono K*.

"Time-resolved transcriptomic profiling of senescence-associated secretory phenotype (SASP) in multiple senescent cell subtypes" (2022 Oct) EMBO Workshop 2022 The DNA damage response, immunity and aging, Singapore. Poster.

Domestic conference

Suda K, Razali N, Moriyama Y, Kono K*.

"Ca²⁺ accumulation in mitochondria mediates plasma membrane damage-dependent cellular senescence" (2022 Nov-Dec), The 45th Annual Meeting of the Molecular Biology Society of Japan. Fukuoka. Pitch and Poster.

MBSJ2022 Science Pitch Award, EMBO Science Pitch Prize