S100A4 in esophageal cancer: Is this the one to blame?

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Abstract

Metastasis is the main reason for cancer-related death. S100A4 is one of the key molecules involved in this event. Several studies have shown that overexpression of S100A4 in non-metastatic cancer cells can make them become metastatic, and knockdown of S100A4 in metastatic cancer cells can curtail their invasive nature. A study by Chen et al published in the World J Gastroenterol 18(9): 915-922, 2012 examined the role of S100A4, one of the well-known cancer metastatic markers, in esophageal squamous cell carcinoma (ESCC) in vitro and in vivo, in animal models as well as in clinical human specimens, and clearly demonstrated a reliance of the invasiveness of esophageal squamous carcinoma on this small calcium-binding protein.

A little biography of S100A4: Short but hot

S100A4 was discovered in the mid 1980s by several laboratories independently. One of these laboratories be-
S100A4 is naturally expressed in various cell types including both cancer and normal cells, and its elevation is usually associated with cell motility. It appears that whenever cell migration is required, such as wound healing, angiogenesis and cancer metastasis, S100A4 is activated. Like other members of S100 family, S100A4 works like a calcium sensor. Upon calcium binding, S100A4 goes through a series of conformational changes, which allow the molecule to interact with its targets, such as nonmuscle myosin heavy chain (MHC II A) and liprin β1, to facilitate cell migration.

For this reason, in motile cells, S100A4 is often found in complex with these cytoskeletal components at the migrating front where a high level of calcium is accumulated. It is interesting to know that S100A4 knock-out mice do not display developmental abnormalities in the postnatal period, but 10% of them develop tumors at age of 10-14 months, possibly due to destabilization of the tumor suppressor p53, as S100A4 has been shown capable to bind to the C-terminal of p53 and repress its transcriptional activity.

Yet, the story of S100A4 is not as straightforward as it might have been anticipated. In addition to being a cytoskeletal regulator in the cytoplasm, S100A4 has also been localized to the nucleus and extracellular matrix. How it gets there and what it does in these locations remain unclear. Nevertheless, its association with transcription factors like p53 might explain some of its roles in the nucleus. It has been postulated that S100A4 binding to the tetramerization domain of p53 favors p53 oligomerization and thereby facilitates p53 nuclear translocation. On the other hand, extracellular S100A4 has been demonstrated to stimulate MMP-13 expression in chondrocytes in a receptor for advanced glycation end products (RAGE)-dependent manner, while its inductivity on neuron growth was found to be RAGE irrelevant.

More complicatedly, S100A4 has been found in association with cell death in a conflict way, it inhibits apoptosis in pancreatic cancer but promotes it in osteosarcoma cells.

**Functions of S100A4: Motivation to move**

Up to date, S100 family includes 25 members with common characteristics such as low molecular weight, two calcium binding sites of the helix-loop-helix (“EF-hand type”) conformation, and complete solubility in ammonium sulfate at pH 7. They have been implicated in regulation of protein phosphorylation, transcription factor activation, calcium homeostasis, cytoskeleton reorganization, cell migration, cell growth and death.

S100A4 is actuated in a variety of cells and tissues, such as nonmuscle myosin heavy chain (MHC II A) and liprin β1, to facilitate cell migration. Like other members of S100 family, S100A4 works like a calcium sensor. Upon calcium binding, S100A4 goes through a series of conformational changes, which allow the molecule to interact with its targets, such as nonmuscle myosin heavy chain (MHC II A) and liprin β1, to facilitate cell migration.
thyroid carcinomas. More direct evidence for the essential role of S100A4 in cancer metastasis perhaps comes from in vitro studies and animal models, which have shown that overexpression of S100A4 in non-metastatic tumor cells confers a metastatic phenotype, just as demonstrated in the study by Chen et al as well as several others; whereas, knockdown of S100A4 in metastatic tumor cells curtails their invasive capability.

It should be pointed out though that S100A4 is not an oncogene product. As shown by transgenic studies, mice carrying extra copies of S100A4 gene develop normally as wild-type and have no increased risk of cancer. However, when these mice mated with cancer mice, their offspring showed increased number of tumors distant from their primary location. Therefore, S100A4 is not a cancer generator but a metastatic facilitator.

S100A4 has been studied extensively in other cancers, especially in breast cancer. In esophageal cancer, there are about a dozen of publications so far, mostly focusing on squamous cell carcinoma. The earliest study that can be found was done by a Japanese group, showing an elevated expression of S100A4 protein in surgically resected ESCC, and a possible association with esophageal cancer progression. However, a later study reported an opposite result, showing that 11 out of 16 S100 family members examined, including S100A4, were down-regulated at transcriptional level in tumors compared with adjacent normal tissues. In 2010, a Chinese research team used RNA interference technology to knock down S100A4 in metastatic esophageal tumor cells and grafted them in nude mice. They noticed that tumor growth was significantly inhibited by S100A4 deficiency, and E-cadherin expression was reciprocal to the level of S100A4. Unfortunately, the study had little impact because it was published in a local journal in Chinese. However, the idea of xenografting has recently advanced to a new cancer treatment strategy - the “avatar” mice. Principally, it is to take tumor tissue from a patient and graft it in nude mice to create a personalized colony of mice carrying exact that patient’s cancer, and then test every potential treatment combinations in mice before selecting the best one to treat that patient. Manuel Hidalgo, the Director of the Spanish National Cancer Research Center in Madrid, has been practicing this approach for pancreatic cancer patients over years and showed a clear advantage in drug responses, and now more and more researchers believe that this idea holds a great promise in cancer treatment in the future.

In the study by Chen et al, the research team cleverly used two ESCC cell lines, EC109 (highly invasive) and TE13 (non-invasive), and successfully made these cells switch characters by down-regulation of S100A4 in EC109 and up-regulation of S100A4 in TE13. They provided in vitro and in vivo evidence that the level of S100A4 determines the metastatic status of the cancer.

There are two main subtypes of esophageal cancer: ESCC and esophageal adenocarcinoma (EAC). Although nearly 95% of esophageal cancer is ESCC, EAC has been rising by 6-fold annually in Americans and now its increase rate exceeds the rate for any other type of cancers. Overexpression of S100A4 was also reported in EAC and its correlation with lymph node metastasis was found significant.

Although the exact molecular mechanisms how S100A4 promotes cancer metastasis still need to be further examined, based on various studies, one possible explanation could be that S100A4 binding to liprin inhibits its phosphorylation, and thereby prevents its interaction with liprin. As a result, liprin fails to recruit leukocyte common antigen-related (LAR) protein, a phosphatase, to focal adhesions. Without LAR to dephosphorylate β-catenin, β-catenin becomes activated to leave E-cadherin and results in the collapse of adherens junctions, allowing cells to migrate. As found in our study, the dissociation of β-catenin from E-cadherin causes E-cadherin ubiquitination and degradation, which might at least in part explains why S100A4 elevation is often found in association of E-cadherin loss, as shown in the study by Chen et al.

S100A4 in normal situation: An innocent bystander

As discussed above, S100A4 is expressed wherever cell migration is required, regardless normal or pathological situation. However, most of S100A4 studies focus on its bad side, such as cancer metastasis and organ fibrosis. Its good side has been continually overlooked. If we go back to the story that S100A4 was discovered in an experiment of serum stimulated fibroblasts, we know that S100A4 is innocent. Cells, including fibroblasts, in our body normally do not come into a direct contact with serum unless there is an injury. Therefore, when cells are suddenly exposed to serum, as the experiment done in Nathans’ lab, they naturally interpret it as a signal of a wound. Therefore, a transcriptional program for wound healing gets activated immediately to battle against injury. S100A4 is just one of the players in this battle. So is SRF, and so are many SRF-regulated genes (e.g., C-FOS, EGR-1, CCN1, CTGF, FGF10, etc). All these genes contain a common regulatory element CArG box, which SRF recognizes to bind. S100A4 gene also contains such element in its promoter region, suggesting a possible regulation by SRF. In vivo, S100A4 activation has been found in various wound healings, and its contributions to tissue repair and modification are indisputable.

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