Mitogen-Activated Protein Kinase Signal Transduction in Solid Tumors

Yuan-Yuan Lei¹, Wei-Jia Wang¹, Jin-Hong Mei¹*, Chun-Liang Wang²*

Abstract

Mitogen-activated protein kinase (MAPK) is an important signaling pathway in living beings in response to extracellular stimuli. There are 5 main subgroups manipulating by a set of sequential actions: ERK (ERK1/ERK2), c-Jun N (JNK/SAPK), p38 MAPK (p38α, p38β, p38γ and p38δ), and ERK3/ERK4/ERK5. When stimulated, factors of upstream or downstream change, and by interacting with each other, these groups have long been recognized to be related to multiple biologic processes such as cell proliferation, differentiation, death, migration, invasion and inflammation. However, once abnormally activated, cancer may occur. Several components of the MAPK network have already been proposed as targets in cancer therapy, such as p38, JNK, ERK, MEK, RAF, RAS, and DUSP1. Among them, alteration of the RAS-RAF-MEK-ERK-MAPK (RAS-MAPK) pathway has frequently been reported in human cancer as a result of abnormal activation of receptor tyrosine kinases or gain-of-function mutations in genes. The reported roles of MAPK signaling in apoptotic cell death are controversial, so that further in-depth investigations are needed to address these controversies. Based on an extensive analysis of published data, the goal of this review is to provide an overview on recent studies about the mechanism of MAP kinases, and how it generates certain tumors, as well as related treatments.

Keywords: MAPK - mechanisms of action - tumor development - treatment

MAPK Signaling Pathway

The mitogen-activated protein kinase (MAPK) signal transduction pathways are evolutionarily conserved among eukaryotes. Normally, the signaling cascades are stimulated by the binding of mitogens, hormones, or neurotransmitters to receptor tyrosine kinases, the transduction of exogenous signals are achieved through sequential phosphorylation (Evans et al., 2013). They are typically organized in 3-tiered architecture consisting of a MAPK, a MAPK activator (MAPK kinase), and a MAPKK activator (MAPKK kinase) (Bagley et al., 2010; Cargnello et al., 2011), leading to the activation of NF-κB, and are relative to cell growth or survival. The kinases MAPK kinase kinases (MAPKKKs) can be phosphorylated by small G-proteins leading to double phosphorylation and activation of downstream MAPK kinases (MAPKKs) (Bagley et al., 2010). The MAPKs acting on their target substrates is said to be initially identified as a mediator of inflammation. In clinical medicine, targeting inflammatory responses in tumors is now a promising trend (Demaria et al., 2010).

Luca Greico et al. has ever used a resulting reaction map to design aqualitative dynamical model with GINsim software, further addressed the roles of cross-talks between the different MAPK cascades (considered as a module for the assembly of more comprehensive cancer-related network) (Grieco et al., 2013; Liu et al., 2013). Usually, Many factors affect these signaling pathways, in a recent study, Luciana R Gomes et al. used transwell assays clarified that the TGF-b1-enhanced migration and invasion capacities were blocked by inhibitors of p38MAPK, ERK1/2 and MMP, indicating TGF-b1 could be a common regulator for MMPs (Matrix metalloproteinases) (Gomes et al., 2012), an important factor in downstream of the MAPK signaling pathway. Also, Isoflavone genistein has been found to inhibit the molecules in the MAPK pathway, leading to the induction of apoptosis perhaps by blocking the activation of p38 MAPK (Li et al., 2011).

Generally, there are 5 main subgroups of the MAPKs: ERK (ERK1/ERK2), c-Jun N (JNK/SAPK), p38 MAPK (p38α, p38β, p38γ and p38δ), ERK3/ERK4 and ERK5: (Figure 1)

The JNK Pathway

The JNKs are encoded by three genes, JNK1, JNK2, and JNK3. the JNK1/2 subtypes are ubiquitously expressed, whereas the JNK3s are restricted mainly to testis and brain. It is an important mediator of apoptosis and cell proliferation. Induction in response to different chemotherapeutic agents and cellular stresses including...
Figure 1. Compositions and Mechanisms of MAPK Signal Pathway. The MAPK pathway is organized in 3-tiered architecture: MAPKKKs, MAPKK, and MAPK, mainly activated by the mitogens and some other physical or chemical factors, during which phosphorylation matter the most. 5 main subgroups compose the MAPK family, that is, ERK (ERK1/ERK2), c-Jun (JNK/SAPK), p38 MAPK (p38α, p38β, p38γ, and p38δ), ERK3/ERK4, and ERK5. And through different ways, they mediate cell growth, proliferation, apoptosis, as well as invasion of cancer cells and inflammation and so on.

heat shock, ionizing radiation, oxidative stress. JNK is normally activated by MKK7 and MKK4. Studies showed JNK1 and JNK2 are involved in the sensitization to cisplatin-induced cell death upon p38 MAPK inhibition and increased ROS levels mediate JNK activation upon p38 MAPK inhibition (Pereira et al., 2013). Actually, there are some interactions between the JNK and the MAPK pathway (Cargnello et al., 2011), JNK isoforms may stimulate the p38 MAPKs, while many MAPKKKs in the p38 module are shared by the JNK module.

The P38MAPK pathway

As is referred above, the p38 MAPK and JNK pathways can cross talk at several levels, mainly in non-transformed cells. But it was not long before the interplay is shown to be mediated by ROST. There are four isoforms of p38 (p38α, p38β, p38γ, and p38δ) (Bagley et al., 2010), also known as stress activated protein kinase (SAPK)2a, 2b, 3, and 4 respectively, which differ in their tissue distributions. The p38 MAPK is selectively activated by MAPK kinases (MKK3/6) (Cargnello et al., 2011) and the mechanism is mediated by dual phosphorylation at the Thr-Gly-Tyr motif. They mediate cell survival or cell death depending not only on the type of stimulus but also in a cell type specific manner. SAPKs/JNKs and p38 are poorly activated by mitogens but strongly activated in cells in response to stress signals.

Generally, the p38MAPK may play an important role in prostate cancer, breast cancer, bladder cancer, liver cancer, lung cancer, transformed follicular lymphoma, and leukemia. Decreasing p38 activity has much to do with cancer since continuous cell proliferation requires the activity of p38 in most of the cancers studied, which is carried out by the activation of downstream targets like ATF-2 and Elk-1.

In other ways, studies have revealed the p38 pathway can result in OIS induced by oncogenic ras or its downstream factor raf-1 through upstream kinases MAPK/ERK kinase (MEK)-ERK MAPK pathway, but isoforms played different roles in OIS (Xu et al., 2014). What’s more, the tumor suppressive effects of the p38MAPK are involved in both the activation of p53 and in p53-induced apoptosis. A recent study by Lorena Pereira et al. shows that p38MAPK can also help tumor cells to survive chemotherapeutic drug treatments. Traditionally, one potential mediator of tumor-induced bone pain is the p38MAPK.

Further, the p38MAPK signaling pathway has been implicated in mediating inflammatory and neuropathic pain, combination of the p38MAPK inhibitors with cisplatin may be exploited for cancer therapy (Pereira et al., 2013). Devki Sukhtankar et al. used a mouse model of breast cancer showed inhibition of p38 MAPK with SB203580 significantly reduced tumor burden (Sukhtankar et al., 2011).

The ERK Pathway

ERK1 and ERK2 are key transducers of proliferation, differentiation, and survival signals. It was originally found to be phosphorylated at Tyr and Thr residues, and almost expressed in all tissues, mainly affecting the growth of cells by G1-to S-phase progression. Generally, growth factors are the most well-known activators (Cargnello et al., 2011), which then cause the activation of upstream kinases MEK1/2 MAPK kinases and Raf MAPK kinases (Bagley et al., 2010). Normally, the ERK3/4 are considered atypical because their activation loop lacks a phosphoacceptor Tyr residue and contains the Ser-Glu-Gly motif. ERK3 is responsible for cell proliferation, cell cycle progression, and cell differentiation, while the function of ERK4 remains unknown (Cargnello et al., 2011); ERK5 (also known as BMK) is activated by various stimuli such as oxidative stress and growth factors and is essential for early embryonic development, it is required for normal development of the vascular system as well as cell survival.

MAPK and Cancer

MAPK and Prostate Cancer

Prostate cancer is the most common non-skin malignancy among men worldwide. Its metastasis to the bone is the main cause of death (Jin et al., 2011). Heredity is one of the strongest risk factors and numerous studies support gene variants, imbalance of SOS (which leads to cumulative damage to lipids), proteins, and DNA (Shen et al., 2010) may potentially contribute to the risks of tumors (Amankwah et al., 2012). But Lifestyle and dietary factors (smoking, antioxidant intake, vitamin D and calcium, and coffee intake) also matter much (Wilson et al., 2012). A number of biomarkers in prostate cancer have facilitated development of targeted treatments (Detchokul et al., 2011). Normally, total serum PSA is a common Marker for detection of prostate cancer (Clarke et al., 2010). Now, MYC acts as a therapeutic target in prostate cancer (Koh et al., 2010). Importantly, the recent cell-based immunotherapy in prostate sets a example for tumor immunotherapy (Drake, 2010).
When referring to the mechanism, we might think of the fashionable notion of chronic inflammatory in which large amounts of reactive oxygen/nitrogen species (ROS/RNS) and cytokines are produced, which then act as a well-recognized cause of cancer. In prostate cancer tissues, people found up-regulation of human epidermal growth factor receptor 2 (HER2) (Sfanos et al., 2012), indicating that the MAPK pathway may play an important role. Also, inflammation-related molecule COX-2 may be over-expressed in prostate cancer, COX-2 can be a transcription factor involved in inflammation-mediated stem cell proliferation (Park et al., 2013) (mainly via prostaglandin E2 (PGE2) (Thanan et al., 2012; Dixon et al., 2013), while in turn, inhibition of COX-2 by lasiodin could down-regulate the MAPK signaling pathways (Lin et al., 2014), which finally reduced bladder carcinogenesis (Thanan et al., 2012). The p38 MAPK signaling is proved to be essential in inflammation, perhaps by regulating the function of macrophages (Yang et al., 2014), in some of these cancers, cytokine IL-6 and IL-6-R which function in activation of inflammatory and androgen receptor (AR) are up-regulated (Sfanos et al., 2012). In other conditions, IL-6 also activates JAK family tyrosine kinases, which in turn activate multiple pathways through signaling molecules MAPK (Ara et al., 2010; Larsen et al., 2011). These mechanisms may conform with our previous knowledge that IL-6 promotes angiogenesis (Ara et al., 2010), invasion (Ara et al., 2010), and attachment (Obata et al., 1997), and the generation of tumor-associated macrophages (Jennin et al., 2011).

The structure and function of the MAPK pathways in prostate are far from being clearly understood (Jennin et al., 2011). But at least, we know for sure that, the p38MAPK protein play an important role in the prostate progress. Normally, in human prostate tissue, the p38MAPK protein is present in the basal cells and epithelial cells of the prostate gland (Mulholland et al., 2012), and it can become active in situations of neoplasia and benign hypertrophy of the prostate gland. MR Milone et.al demonstrated by using zoledronic acid (ZOL) inhibits and a resistant subline of prostate cancer cells, that the p38MAPK pathway had something to do with drug resistance and invasion of cancers (Milone et al., 2013), the latter is said to be mediated by the downstream compositions MMP-2 and MMP-9 (Bourbouila et al., 2010; Mao et al., 2010; Kessenbrock et al., 2010; Milone et al., 2013). In prostate cancer, hormone may be an important factor. Hari K. Koul et al. have observed in immunoprecipitation that the p38MAPK which results in decrease in AR levels and activity in prostate cancer cells in culture (Koul et al., 2013) can associate AR assays while amplification of the AR gene allows the receptor to respond to lower levels of androgens (Kohl et al., 2010). Aiming at this mechanism, there came out a new treatment-androgen deprivation therapy (ADT), referring to any intervention which results in the androgen receptor of target cells not being activated (Connolly et al., 2012). As we know, FGF-1 and KGF -2, IL-6, HB-EGF, TP, vitamin D, carbachol, osmotic shock, and UV light can act as stress response to cause p38 activation (Koul et al., 2013), while in another way, over-expression of α-PAK, MEK-6, p38, p-Elk-1, and p-ATF-2 occur in benign prostate hyperplasia and more intensely in prostate cancer patients, enhancing cell proliferation and survival, What’s more, Mol Cancer Ther et.al claimed activating of the p38MAPK pathway might lead to stabilization of p75NTR mRNA and therefore increased levels of p75NTR protein which said treatment with R-flurbiprofen or ibuprofen induced p75NTR expression acted as a sensitive factor in Prostate cancer cells (Khwa et al., 2008). In another event, to further clarify the signaling pathway in prostate cancer, David J Mulholland et al. crossed conditional activatable K-rasG12D/WT mice with the prostate conditional Pten deletion model and found that Ptenloss and RAS/MAPK activation cooperated to promote EMT and metastasis. Inhibition called PD325901 and MEK inhibitor significantly reduced the metastatic progression, and they reported the important collaborative effects of RAS/MAPK and PTEN/P3K pathways in promoting prostate cancer metastasis. Interestingly, in prostate cells, oncogenic ETS proteins (linking to prostate cell migration behavior) were found to be able to replace RAS/MAPK pathway activation by a specific binding pattern while aberrant expression of oncogenic ETS transcription factors are implicated in the majority of prostate cancers (Hollenhorst et al., 2011). While for the rat family, there are other active ways, in a mouse model of advanced prostate cancer, Jingqiang Wang found inducible expression of a BRAFV600E could activate the ERK1/2 MAPK, leading to up-regulation of the c-Myec oncogene (Wang et al., 2012).

MAPK and Breast Cancer

Breast cancer is the leading cancer diagnosis in women aged 20-45. Risk Factors of breast cancer include breast density (a highly heritable quantitative trait) (Boyd et al., 2010), age, family history, parity, and so on (Westbrook et al., 2013). To be more accurate, estrogen receptor (ER), progesterone receptor (PR) and HER2 expression are of great importance (Liu et al., 2013). For example, cell proliferation inhibitor Emodin is justly proved to function in a MAPK way, targeting at ERα (Jia-Qi et al., 2014). But endocrine therapy targeting at ER or HER don’t receive much effect as imaged, now, researches have showed that the ERK is closely connected to hormone resistance by the oncogenic RAS-MEK-ERK pathway (Polio et al., 2010). So, specific inhibitors of ERK kinase (MEK) should be of help. In modern medical science, there are more targeted therapies, multidisciplinary including the macroscopic and microscopic way can result in prolonged disease control (Cheng and Ueno, 2012).

In breast cancer the p38MAPK also matters much, it acts as a central kinase in a common pathway that plays an important role in breast cancer invasion and metastasis by modulating the expression and activity of molecules involved in the degradation of extracellular matrix (mainly MMP-2 and MMP-9) (Slattery et al., 2013). Normally, it can be activated by TGF-β signals through transmembrane receptor kinases by a Smad-dependent and Smad-independent mechanisms as well as the MAPK4 pathway (Koul et al., 2013). But the TGF-β relative mechanism has
been revealed recently to be blocked by a medicine called Curcumin (Mo et al., 2012).

Recently, Lorena Pereira et al. used MMTV-PyMT mouse model of breast cancer proved a p38 MAPK chemical inhibition cooperated with cisplatin to reduce breast tumor size (Pereira et al., 2013), and melatonin is proved to play an inhibitory role in breast cancer cell invasion in the p38 pathway (Bourboulia et al., 2010; Mao et al., 2010; Kessenbrock et al., 2010; Milone et al., 2013). Fanyan Meng et al. also invested biologic function of p38γ MAPK in breast cancer. Through gene expression, knockdown, chemotherapeutic agents, observation of biologic effect, they identified that over-expression of the p38γ MAPK led to marked cell cycle arrest in G2/M phase. What’s more, they said the main function of p38γ MAPK in breast cancer was to maintain the oncogenic properties rather than to promote cancer progression (Mimura et al., 2013). All these indicate that p38γ MAPK is a promising target for the design of targeted therapies for basal-like breast cancer.

Not long ago, the MAPK-ERK was found to be the predominant pathway promoting notch activation in MDA-MB231 cells referring to breast cancer, the study was carried mainly by a kinase inhibitor library that contained 240 kinase inhibitors. And during the process, TRB3 act as a master regulator (Izrailit et al., 2013). Apart from these, a mutant form of H-Ras can strongly activated p38 MAPK, and actually, activation of the RAS-RAF-MEK-ERK-MAPK pathway is commonly observed in human breast cancers (Cerne et al., 2012). But Yashaswi Shrestha et al. found other genetic alterations, a breast cancer oncogene PAK1 (amplified in 30-33% of human breast tumors) coordinate activates MAPK signaling (Shrestha et al., 2012). Interestingly, as PTKs and their downstream signaling pathways contribute to critical biological functions relevant to the cancerous phenotype, Brk should be over-expressed in invasive breast carcinomas (Loßgren et al., 2011). From reports of Kristopher A. Lofgren et al., we know that p38MAPK may contribute to progression in human breast tumors as a downstream signaling mediator of Brk (Lofgren et al., 2011).

As for other mechanisms, we may know from previous reports, that programmed cell death was significantly increased in the cells with low IGF-IR expression and this increased cell death might be mediated through activation of the p38 MAPK (Mendoza et al., 2010).

With these, Rhone A Mendoza et al. further cloned cell lines with significantly reduced expression of the p38 MAPK. And concluded that the effects of p38 MAPK in regulating growth of breast cancer depended on whether the tumors expressed intact or mutated form of p53 (Shrestha et al., 2012), an important tumor suppressor gene whose inactivation can cause many human cancers. As for triple-negative breast cancers (TNBCs), one of the most aggressive forms of breast cancer with poor clinical outcomes owing to a lack of targeted therapies, activation of the MAPK pathway should be responsible for resistance to conventional chemotherapy, revealing that down-regulating of the MAPK pathway is crucial in the novel targeted therapy for TNBC. Wondrously, S Gholami et al. demonstrated that oncolytic viral therapies were of great promise, and at present, viral therapy with NV1066 can cause a significant decrease in the p-MEK and p-MAPK (Gholami et al., 2014).

**MAPK and Bladder Cancer**

Generally, age, gender, race, environmental agents, chemicals, cigarette smoking, radiation, infection, and hereditary are thought to be of significance in bladder cancer (Tanaka et al., 2011). But genetic variation matters the most (Dudek et al., 2013). Nowadays, genome-wide association studies (GWAS) which based on the case-control design can predict underlying cancers (Dudek et al., 2013). And as the epidermal growth factor receptor (EGFR) is frequently over-expressed in bladder cancer (Komper et al., 2010), it can be an important therapeutic target.

Activation of MAPK is a frequent event in tumor progression and metastasis. In bladder cancer, for the ras family, a regular activator, their mutation can cooperate with b-catenin activation to drive bladder tumourigenesis (Ahmad et al., 2011). To be more specific, the KRAS and HRAS mutations occurred with equal frequency. While NRAS mutations were less (Komper et al., 2010). Still, Lan Mo et al. claimed over-activation of Ha-ras occurred in human urothelial tumors and hyper-activation of the ras signaling pathway was responsible for the low-grade, non-invasive papillary bladder tumors (Mo et al., 2007).

Then, for the p38MAPK, Hari K. et al. found that it was activated during the log phase growth of bladder cancer cells and it could modulate MMP-2 and MMP-9 expression (Koul et al., 2013), which composed the usual inflammatory mechanism, while cancer itself could cause inflammation through the production of pro-inflammatory factor MMPs (Matrix metalloproteinases) (Thanan et al., 2012), linked to cancer metastasis and tumor suppression (Walia et al., 2012; Mohammad et al., 2013). Then, a considerable vicious circle comes into being (Mohammad et al., 2013). Studies have revealed that TNF-α could regulate MMP-9 expression through NF-κB, AP-1, while p38 MAPK kinase mediates TNF-α-induced MMP-9 expression (Koul et al., 2013). It has also been shown that the p38 MAPK is essential for the down-regulation of COX-2 expression (responsible for cell proliferation, metastasis, and angiogenesis), and during the process, sulforaphane (SFN), a dietary isothiocyanate in human bladder T24 cells matters much.

**MAPK and Liver Cancer**

Hepatocellular carcinoma (HCC) is a deadly cancer, with high mortality and poor prognosis, whose incidence is increasing worldwide. Normally, hepatitis B (Philbin et al., 2012) and hepatitis C virus infection are said to be an usual way of obtaining the liver cancer (Chang et al., 2010), and alcohol abuse can add to the risks. In some cases, the stem cells have the potential for therapy of liver diseases, but may also be involved in the formation of liver cancer (Rountree et al., 2012). Not long ago, Zhigang Lv et al. concluded that TGF-β1 could persistently activate ERK and p38MAPK signaling in HSCs (Lv and Xu, 2012). Now, deregulation of TGF-β signaling is
acting as a molecular pathway to TISC-based malignancy (Rountree et al., 2012).

Normally, p38 MAPK activities in human HCCs are significantly lower, while attenuation in the p38MAPK and MKK6 activities in human HCC tissue specimens may cause the resistance to apoptosis, leading to unrestricted cell growth of human HCCs (Lamy et al., 2013). Previous research also shows TNF-α and IL-1 are elevated in liver cell injury and may activate the p38 MAPK pathway (Lamy et al., 2013)

Further, as we all know that telomerase provides a promising target for a selective therapeutic approach of malignancies. Taking telomerase positive HCC cell lines for example, activation of all three MAPK (JNK, ERK1/2 and P38) can be observed, while activated ERK1/2 and P38, but not JNK, is related to telomerase abrogation and consequent apoptosis induction (Lamy et al., 2013). Consistently, blockade of JNK activation promotes cell survival and stimulates p38 MAPK mediated by MKK3/6 and MKK4/7 in human hepatoma cell lines (Lamy et al., 2013).

And like many other cancers, the RAS cascade (RAS-RAF-MEK-MAPK pathway) can also be found in liver cancer, resulting in proliferative and anti-apoptotic signals (Zender et al., 2010). Strangely, Chunmei Wang, et.al noted that AKT/mTOR and Ras/MAPK interacted with each other in hepatocarcinogenesis in a mouse model characterized by the co-expression of activated forms of AKT and Ras in the liver (Wang et al., 2013), which might advanced the targeted treatment for HCC. Apart from these, through series of cell culture and in vitro experiments, Margaret A. Park, et.al demonstrated that, in the typical signal way, MEK 1/2 inhibitors could interact with many other pharmaceuticals in killing hepatoma cells (Park et al., 2008).

MAPK and Lung Cancer

Generally, lung cancer is divided into non-small-cell lung cancer (NSCLC) and small-cell lung cancer (SCLC). Tobacco smoking, gender, race and ethnicity, age, diet, obesity, infections, environment, and other Lung diseases or airways obstruction, all contribute much in lung cancer occurring (Egleston et al., 2009; Dela Cruz et al., 2011; Larsen et al., 2011). Also, multiple gene variations shown some roles in lung cancer, which says comprehensive analyses should be necessary (Marshall and Christiani, 2013), and we can notice that 90% of the mutations are located in KRAS, which then activates the RAS/RAF/MEK/MAPK pathway (Larsen and Minna, 2011; Larsen et al., 2011; Kadara et al., 2012), indicating KRAS in lung tumorigenesis may be a significant therapeutic target. And in this way, the MYC (regulator of cell proliferation) acts as main downstream factor (Larsen and Minna 2011). So, based on these mechanisms, K-ras mutations, EGFR (also related to phosphorylation and tyrosine kinase) mutations, copy number, and expression, should be better molecular biomarkers for patient selection (Larsen et al., 2011; Hassanein et al., 2012). In clinical medicine, there are also other markers such as COX-2, p53 (de Mello et al., 2011).

As is known for all, the inflammatory cytokines play an important role in airways inflammation and allergic mechanisms (Koul et al., 2013). It is suggested that p38 MAPK would have an impact in these factors mainly mediated by LPS-induced cytokines that mediate chronic lung diseases and consequently leading to cancer. As a rather common factor in the inflammatory progress, IL-6 is also proved to elevate COPD-like inflammation, and lack of IL-6 resulted in a 41% reduction in the visible tumors on the lung surface (Ochoa et al., 2011). Apart from these, Cesar Ochoa Perez et.al found up-regulation of MMPs (downstream substrates of the MAPK), especially MMP-12, in lung cancers which related to the COPD (Ochoa et al., 2011).

For the NSCLC, in which EGFR exhibits over-expression or aberrant activation in 50-90% of cancer cells (Larsen and Minna, 2011), Eva M. Galan-Moya et al demonstrated by innovatively using transformed cell lines that the interplay between MAPKKs was crucial for p38 MAPK activation in response to cDDP (Cisplatin) and proposed that the imbalance between MKK6 and MKK3 could be a potential biomarker for NSCLC, while MKK3, but not MKK6, was the critical player, although MKK3 controls MKK6 levels in NSCLC derived cell lines through activation of p38 MAPK (Galan-Moya et al., 2011).

When referred to treatments, through control experiment, J Cell Biochem.et.al proved that PBA (an experimental compound) had some therapeutic effectiveness, mainly by mechanisms such as increasing cell-cell communication, decreasing activation of JNK, up-regulation of p38 MAPK activity (Matesic et al., 2012). And Herbal medicines such as Radix Tetrastigma Hemsleyan Flavone (RTHF) can promote apoptosis via regulation of ERK and p38 phosphorylation (Zhong et al., 2013). In other experiments, by knocking down and over-expression of EAPII in NSCLC, C Li et.al found that EAPII significantly affected Raf1 and ERK1/2 (important composition of the MAPK signal pathway) and during the process, the MAPK-ERK pathway which elevates levels of MYC and cyclin D1 was activated. In their hypothesis, EAPII has an oncogenic role in lung cancer development (Li et al., 2011a), As for the Ras/MAPK pathway, EGFR protein activates both K-Ras 4B and H-Ras in different ways, and affects nuclear transcription of several downstream genes in a GTP-dependent way (de Mello et al., 2011).

MAPK and Gastric Cancer

Gastric cancer is said to have some things to do with age, sex, geography, dietary, occupation, lifestyle and heredity (Nagini, 2012). Previous research have claimed, that the whole progress is associated with multiple genetic and epigenetic alterations of oncogenes, tumor suppressor genes, DNA repair genes, and other molecule mechanisms (Nagini, 2012). In the modern society, PET, PET/CT imaging (Wu and Zhu, 2014) and availability of gastrointestinal endoscopy have significantly improved the diagnosis of gastric cancer.

Actually, the protein tyrosine kinases (PTKs), EGF-like domains 1 (TIE-1) and mitogen-activated protein kinase 4 (MKK4), can be detected as new molecular biomarkers for gastric cancer prognosis (Wu et al., 2014).
Now, minimally invasive surgery is regarded as one of the standard treatments for early gastric cancer (Son et al., 2014), and acid suppressive drugs such as H2R blocker or PPI may act as a stimulator for gastric cancer (Ahn et al., 2013).

For the pathogenesis, on-cogenes such as K-ras and c-erbB2 (both act as important roles in the MAPK signal pathway) may mutate in gastric cancer (Nagini, 2012), causing abnormal growth cycle in gastric cells, and at the same time, vascular endothelial growth factor (VEGF), related to invasion and angiogenesis by reducing cell-cell adhesion is found over-expressed in the cancer cells (Nagini, 2012; Chao et al., 2013). Experiments showed that once the P38MAPK was inhibited. So was the express of VEGF. And phosphorylation of the JNK may also be positively relative to cell proliferation and the VEGF expression. But activation of the ERK1/2 and PI3K/Akt pathways were thought to be the vital one in tumor progression (Chao et al., 2013). In some case, VEGF-dependent tumor angiogenesis is resulted by interaction of VEGFR1 and VEGFR2 (Zhang et al., 2010), while it is also believed that VEGFR1 signaling is responsible for endothelial cell survival, but VEGFR2 regulates capillary tuber formation (Zhang et al., 2010).

In other ways, Kousaku Mimura et.al proclaimed the MAPK pathway regulated HLA-A expression in gastric cancer (Mimura et al., 2013), while reduced expression of HLA class I on tumors is often associated with disease progression and poor prognosis in diverse human tumors.

And except from above, the matrix metalloproteinases (MMP) family (downstream molecules of the MAPKs) can alter cancer microenvironment and may function in cancer invasion through over-expression. Sanjib Deyet al have revealed that MMP-1.3, MMP-1.4 and MMP-1.5 polymorphisms in the MMP-1 promoter enhances the risk of lower stomach tumor formation in an eastern Indian population (Dey et al., 2014).

MAPK and Melanoma

Melanoma is a malignancy of melanocytes, as well as the fastest growing and most fatal form of skin tumor. Over-exposure to ultraviolet radiation and sunburn exposure may add the risk (Curiel-Lewandrowski et al., 2012), which can be more susceptible in younger people (Curiel-Lewandrowski et al., 2012; Korner et al., 2013). Reducing rates of sun-burnt, Early Detection, Melanoma (Curiel-Lewandrowski et al., 2012; Korner et al., 2013), which can be more susceptible in younger people (Curiel-Lewandrowski et al., 2012; Korner et al., 2013).

The mitogen activated protein kinase (MAPK) pathway (consist of RAS, RAF, MEK1/2 and ERK1/2), has been identified as a key player in melanoma development making this cascade an important therapeutic target (Tsao et al., 2012; Falchook et al., 2012; Ades and Metzger-Filho, 2012). In melanoma, the RAS family, a monomeric guanosine triphosphatases that are normally activated by mutation or cell surface receptors (related to extracellular signals), function as molecular switches to control cell proliferation and survival. Activated RAS (GTP-bound) triggers the formation of the “MAPK complex” with downstream RAF, MEK1/2, ERK1/2 and several scaffolding proteins to initiate the MAPK cascade, and during the processing, phosphorylation regulates the expression of several downstream genes (Inamdar et al., 2010; Evans et al., 2013).

Through researching the previous studies, MA Davies et.al concluded that activated NRAS activated both the RAF-MEK-ERK pathway and the PI3K-akt pathway (Davies and Samuels, 2010; Rebecca et al., 2012; Tsao et al., 2012; Evans et al., 2013), which is frequently implicated in oncogenesis, he also found that, the BRAF (coding a serine/threonine kinase protein), a component of the RAS-RAF-MEK-MAPK pathway, once found mutated, can also activate the RAS-RAF-MEK-MAPK pathway (Rebecca et al., 2012; Walia et al., 2012; Tsao et al., 2012; Ades and Metzger-Filho, 2012; Evans et al., 2013), similar to mutant RAS (Davies and Samuels, 2010; Tsao et al., 2012), which lacks GTPase activity and remains active leading to uncontrolled cell proliferation (Evans et al., 2013). Further, the BRAF can collaborates with the PI3K/akt pathway in hyper activating the MAPK pathway (Lin et al., 2010), usually, when RAF becomes activated by tyrosine kinases ,it activates the MAP kinases MEK 1 and 2, which are then phosphorylated and translocated into the nucleus to bind promoters of genes involved in the induction of cell growth and proliferation. All these shows inhibitor of BRAF such as V600E BRAF should be an effective treatment (Rebecca et al., 2012; Ades and Metzger-Filho, 2012). The MEK inhibitor selumetinib can also help (Falchook et al., 2012). However, drug resistance limits their clinical application, but strangely, MA Davies et.al knew from other documents that all the drug resistance mechanisms seemed to share continued activation of the RAS-RAF-MEK-ERK signaling pathway (Davies and Samuels, 2010; Rebecca et al., 2012).

When concerning other treatments of Melanoma, Gajanen S.et.al summarized several methods including targeting RAS, B-RAF, MEK, ERK, nanotechnology, crosstalk between AKT3 and MAPK pathway, phosphatase-deregulation and said that combined targeting of the members of MAPK cascade or oncogenic proteins from different signaling pathways will be required to achieve better clinical efficacy (Inamdar et al., 2010). Silymarin, a polyphenolic flavonoid isolated from Silybum marianum, is said to inhibit COX-2 activities and suppress invasion by inactivating PI3K-Aktas and MAPK pathways, and therefore reducing MMP-2 as well as MMP-9 protein levels (Madhunapantula and Robertson, 2012). Berberine, a COX-2 inhibitor, functions in inhibiting melanoma cell proliferation and metastasis by targeting COX-2 and ERK pathways (Madhunapantula and Robertson, 2012). To conclude, in clinical medicine, there are drugs targeting MEK 1/2, MEK, RAF, RAS, and some other Pathways (Evans et al., 2013).

MAPK and Ovarian Cancer
Ovarian cancer is a common disease among women, and is said to be connected to reproductive disorders, age, and hormone (Merritt and Cramer, 2010; Modugno et al., 2012). There are three major types: epithelial, germ-cell and stromal cancer. Recently, there are many antiangiogenic therapies are under clinical application, such as anti-VEGF therapies, tyrosine kinase inhibitors [TKIs], Poly-ADP-Ribose Polymerase (PARP) Inhibition, PI3K inhibitors AKT inhibitors, and MEK inhibitor (Westin et al., 2013; Coleman et al., 2013).

In a newly published result, KA Bauckman et al elucidated iron (rich in the cyst fluid of endometriosis-associated ovarian cancers) levels were essential for cell (especially ovarian cancer cells) survival, for it induced an increase in lysosome numbers in a ras-independent manner (Bauckman et al., 2013). While as introduced above, ras is closely associated with the MAPK pathway in the casacade RAS-RAF-MEK-ERK-MAPK. Also, studies have showed that mutations in KRAS (MEK1/2) could not only activate MAP Kinase (MAPK or ERK), which induce the over-activation of NF-κB (related to anti-apoptotic mechanisms) (Saldanha and Tollefsbol, 2014), but also the PI3K/ AKT pathway (Merritt and Cramer, 2010; Saldanha and Tollefsbol, 2014) which is commonly considered to result in many cancers (Merritt and Cramer, 2010; Saldanha and Tollefsbol, 2014). Further, Charles et al showed that progesterone elevated cAMP levels, then resulted in activation of JNK1/2 and p38 MAPK activity and subsequently leading to induction of pro-apoptotic genes like Bax (Charles et al., 2010). So, we may conclude inhibition of the MAPK pathway could reverse cell death in malignant ovarian cells.

Surprisingly, Melissa A. Merritt et al concluded from previous research that alterations in the MAPK signaling cascade, acted as the most important factor that distinguished serous low grade from serous high grade ovarian tumors (Merritt and Cramer, 2010). And except from the above MAPK pathway, hormones such as follicle stimulating hormone (FSH) and luteinizing hormone (LH) may also function much through MAPKs leading to over-growth of cells (Saldanha and Tollefsbol, 2014). So, hormonal therapies may be a nice choice (Jelovac and Armstrong, 2011).

Finally, as an important target protien of the MAPK signal pathway, the AR is expressed in both normal ovary and ovarian cancer. The ovarian cancer cells express AR and respond to androgen with increased proliferation and attenuated apoptosis. Over-expression of AR has been found in ovarian cancer, and once activated, it can stimulate ovarian cancer cell invasion (Gogoi et al., 2008; Ligr et al., 2011), indicating targeting AR is also a promising treatment strategy.

Conclusions and Future Directions

Cancer has long been a vital cause leading to death. The cancer-related fatigue can bring about not only additional economic burden, but also exhaustion and lack of energy.

In the cancer process, genetic and epigenetic modification are thought to cause a variety of abnormal phenotypes including increased proliferation and survival of somatic cells. Normally, enhanced telomere attrition, oxidative stress, ultraviolet radiation exposure, severe DNA damages and oncogenic events can all act as activators to regenerate all kinds of signal ways related to mutations in genes or some other molecules. During the course, various gene products or factors, such as growth factors, protein kinases, and inflammatory mediators contribute to tumor progression. And actually, all the changes may be linked to some certain signal ways, which can cross-talk with each other. So treatments to certain cancers would be obtained by targeting several pathways. Although we have known that the MAPK pathway which related to cell proliferation, growth, transport, death, and many vital factors matters much in many human tumors.

Actually, in today’s world, many mechanisms about the signal pathway have been revealed, for advances in our understanding of the genetic composition of cancers make some analyses potentially feasible but how it functions in certain cancers still remains unclear, methodology allowing for robust and cost-efficient analyses are far from enough. So further or comprehensive researches such as genome-wide association studies in cancer may find its way in current and future directions which would easy our way toward finding more targeting treatments or significant markers in the tumor field.

Acknowledgements

This research project was supported by grants from the National Natural Science Foundation of China (No.81260372) and the Natural Science Foundation of Jiangxi Province (No.20114BAB205047).

References

Cargnello M, Roux P (2011). Activation and function of the


facilitators of adherence to medical advice on skin self-examination during melanoma follow-up care. BMC Dermatol, 13, 3.


Yuan-Yuan Lei et al.


