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Reply: Purine metabolite levels in preovulatory human follicles may hold the key to ovarian hyperstimulation syndrome

To the Editor:

We are in agreement with Valerio Napolioni that adenosine's importance in reproductive biology may be wider and more variable than the association with energy charge that we describe. Indeed, we feel that the potent pharmacology of this purine may be unwelcome under emerging circumstances. Tremendous progress has been made in assisted reproductive technology since the birth of the first baby in 1978 by in vitro fertilization (IVF). The development of intracytoplasmic sperm injection in the early 1990s further increased the pregnancy and live birth rates [1]; nonetheless, a serious iatrogenic illness arose from this technology in the form of ovarian hyperstimulation syndrome (OHSS). This is experienced by approximately 5% to 10% of women undergoing IVF; and the clinical symptoms of OHSS are graded mild, moderate, and severe. Mild symptoms include abdominal bloating and feeling of fullness, nausea, diarrhea, and slight weight gain. The progression to moderate symptoms is defined by excessive weight gain (weight gain of >2 lb/d), increased abdominal girth, vomiting, diarrhea, concentrated urine, and excessive thirst. Severe symptoms are marked abdominal distension due to ascites, pulmonary edema, and chest pain [2].

The molecular cause of OHSS has been put down to a soluble factor found to be produced by multiple follicles that arise as a result of deliberate ovarian stimulation. Research into follicular fluid has been undertaken in many different ways: immunoassays for specific molecules or hormones [3-5], proteomic studies by 2-dimensional electrophoresis and mass spectrometry analysis [6], and granulosa cell messenger RNA quantification for inhibin-activin-follistatin system by polymerase chain reaction [7]. The primary focus in the search for the molecular agent responsible for OHSS has centered on vascular endothelial growth factor (VEGF), perhaps because of our current preoccupation with genes and proteins rather than smaller potent bioactive molecules. There is a presumption that VEGF levels are supraphysiologic in follicular fluid and will cause local blood vessels to become leaky [2]. Unfortunately, VEGF levels are not particularly elevated in follicular fluid compared with other sources [8]. However, smaller vasodilatory purine metabolites are present in follicular fluid in abundance [9]. In the 1980s, Downs et al [10] studied their roles as meiotic inhibitors (in mice predominantly). Later, Lavy et al [11], studying purine metabolite levels in human follicles from both natural and stimulated cycles, claimed that adenosine was the inhibitor of human oocyte maturation. In our recent study, we found that hypoxanthine levels were extremely variable, but adenosine was a consistent component, and levels were supraphysiologic—the smaller follicles contained a much greater concentration of adenosine than the larger ones [9].

Adenosine's other biological actions make it a significant contender as the molecular cause of OHSS: adenosine is a powerful vasodilator; and when administered by intravenous infusion, it can produce substantial hypotension. Acting via adenosine A2 receptors, it induces smooth muscle relaxation, especially in the coronary circulation; but because of its extremely rapid metabolism, it is very short acting. It is common practice to infuse adenosine into coronary arteries when imaging occlusions, but it is not used clinically as a vasodilator. However, in such patients, most of adenosine's side effects are related to its vasodilatory properties. Furthermore, peripheral microvascular endothelia local production of vascular permeability factor/VEGF A is up-regulated 2- to 3-fold by adenosine [12].

A wave of symptoms due to vasodilation and increased vessel permeability spreading from the ovaries to the abdomen and on to the lungs would be consistent with unopposed peritoneal infusion of adenosine (leaking from multiple follicles). This is prevented by adenosine deaminase, or ADA (also referred to as *adenosine aminohydrolase*, EC 3.5.4.4), a ubiquitous enzyme that appears to be particularly important in the development of thymocytes. ADA converts adenosine into inosine through the hydrolysis of the purine amino group, with an estimated half-life of 1 second (Fig. 1). ADA is present in all tissues, but activity is particularly high in thymocytes of the thymic cortex. There are 2 enzymes that carry out ADA activity, called *ADA1* and *ADA2*. ADA1 a 40-kd monomeric protein with a 200-kd noncatalytic combining protein, and it is responsible for about 90% of adenosine deamination. ADA2 is somewhat larger at 110 kd and appears to play a general adenosine deamination role in serum. Total absence of ADA activity results in a form of severe combined immunodeficiency.

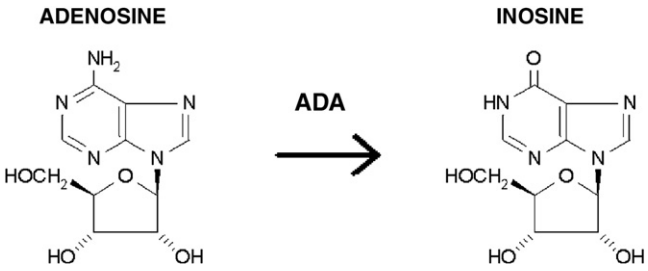

Fig. 1. Adenosine is deactivated by its rapid conversion to inosine through the hydrolysis of the purine amino group by ADA.

However, as pointed out by Valerio Napolioni, polymorphic variants have now been found with reduced rates of catalytic activity. In some circumstances, this is positively advantageous. Adenosine is released by cardiomyocytes in response to ischemia and is cardioprotective in this regard [13]. Genotypic variants resulting in reduced metabolism of, or increased receptor response to, adenosine result in a phenotypic group more likely to survive ischemic events [14,15]. The question to be investigated is this: do these same genotypes result in an IVF patient phenotype prone to the development of OHSS?

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How the "A" to "C" conversion may create a new splice acceptor site?

To the Editor:

We have read with great interest the article by Katsumata et al entitled "Novel intronic *CYP21A2* mutation in a Japanese patient with classic salt-wasting steroid 21-hydroxylase deficiency" [1].

The authors report a novel *CYP21A2* mutation (IVS-9A>C) at −9 position of intron 9 in a Japanese male patient suffering from a severe classic form of congenital adrenal hyperplasia.

Katsumata et al perform complex in vitro experiments showing that the transient expression of the *CYP21A2* IVS-9A>C mutation in COS-1 cells creates an aberrant splice acceptor site at −7 position of intron 9, inactivating the original slice acceptor site. The result is the complete deficiency of 21-hydroxylase activity and loss of immunoreactive CYP21A2 protein.

In line with the reported data, we now ask ourselves how the "A" to "C" conversion at −9 position of *CYP21A2* intron 9 may create a new splice acceptor site. Generally, a canonical acceptor splice site is "AG"; and only this consensus bases sequencing can be correctly recognized by splicing factors [2].