Chapter 2
General Overviews on Applications of ELISA

Abstract Current chapter reviews the applications of ELISA in various different fields including food industry, vaccine development, immunology (autoimmunity and humoral immunity), diagnosis (pregnancy, cancer and infectious diseases), toxicology, drug monitoring, pharmaceutical industry, and transplantation. Different examples related to each area are explained. ELISA was found to play major roles in all the mentioned disciplines.

2.1 Applications of ELISA

Following the history of the immunoassays until the invention of ELISA, different types of biomolecular entities involved in the assay procedure and the interaction types between such molecules, which were described in previous chapter, the current chapter provides a general overview on the broad spectrum of ELISA's applications. Several examples for applications of this widely applied technique in the areas of food industry, vaccine development, immunology, diagnosis, toxicology, drug monitoring, pharmaceutical industry, and transplantation are briefly reviewed.

2.1.1 Food Industry

ELISA plays a major role in food industry. It is the main platform for identifying food allergens such as those present in milk, peanuts, walnuts, almonds, and eggs [1]. Peng et al. developed a monoclonal antibody based sandwich ELISA for the detection of ovalbumin in food, which is the most frequent cause of food allergy, especially in children. ELISA can also be employed to corroborate the authenticity of the food products [1]. This technique is of great help to avoid possible economic losses caused by fraudulent substitution [2]. In the case of meat and meat-based products, ELISA has proven to be a reliable technique that provides careful monitoring of the product, especially when religious considerations in the choice of food

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are concerned [2]. ELISA is also an essential technique for quality control of fish, milk (as well as their sub products), genetically modified foods, irradiated foods, or other harmful food components that can be transferred to human, such as bovine spongiform encephalopathy [2]. Non-meat proteins such as soybean have valuable nutritional properties. Nonetheless, due to the similarity to the mean product, they are seldom added to the meat products undeclared. Careful monitoring of the products with ELISA prevents such adulteration [2]. Unethical competitions for higher economic gain often lead to the potential health hazard through the consumed food and beverage.

Production of ELISA kits for food industry applications is challenging as a selection of adequate control and standard samples is necessary to carefully calibrate the assay [3]. Additionally, ELISA can target different types of analytes in the same food sample, thus the manufacturers should provide a complete set of kit components for the potential target biomolecules [3].

2.1.2 Vaccine Development

ELISA serves as a great candidate for vaccine development. The sera sample from immunized animal or human model can be tested to detect the presence of antibodies against certain types of antigens, which were intentionally injected to the host [4]. Normally different antigens are used to produce immune reactions in the host, among which those that elect higher protection response with less adverse effects can be selected [5].

The main challenge in application of ELISA in vaccine development is the appropriate choice of positive and negative controls. In the experimental stage of vaccine development and when dealing with unknown samples, it is particularly difficult to achieve high analytical precision [5]. Nonetheless, ELISA technique has proven to have a unique position in profiling of elicited immune responses, which are widely performed for vaccine trials around the world [6, 7].

2.1.3 Immunology

The defender of the body, the immune system, can operate in cellular or humoral (innate or adaptive) modes [8]. Measuring and monitoring the changes of the immune response underlay the foundation for understanding immune disease. Various studies have demonstrated ELISA as the gold standard method that is rapid and cost-effective for such measurements and monitoring [9].

A great number of examples for ELISA applications in immunology are reported, while some efforts were directed to optimize ELISA protocols further and to validate/establish their accuracy, sensitivity and specificity to support the clinical practice [10]. In this section, we describe some of these examples.

2.1.3.1 Autoimmunity

Multiple infections, environmental factors, and mild immune system failings trigger an autoimmune response through uncontrolled immune system activation [11]. The body produces antibodies in response to different types of external pathogens. These external pathogens can be particles or epitopes that penetrated the cells but later have become part of the cells' structure. In such situation, antibodies react against the cells themselves thus resulting in an immunodeficiency-oriented phenotype.

Pulmonary alveolar proteinosis (PAP) is an example of an autoimmune disease, which is characterized by accumulation of surfactant in the alveolar system [10]. This disease has found to be associated with autoantibodies that are produced against the granulocyte/macrophage-colony stimulating factor (GM-CSF). When a pathogen enters the respiratory system, GM-SCF is needed in order to regulate the infection [10]. To study PAP, radiology and cytology analyses can be of great help. Additionally, ELISA can assist clinicians in identifying the thresholds associated with the risk of PAP.

Bullous pemphigoid, an acute/chronic skin illness, is another example of autoimmune disease known for its high mortality rate. Typically, it can be diagnosed through its clinical features and histopathological analysis. However, ELISA has shown high sensitivity and specificity in detecting circulating autoantibodies against the corresponding epitope to this illness [12]. Paper-based ELISA platforms have demonstrated a rapid, cost-effective, and convenient diagnosis/monitoring method of this disease [12].

The incidence of autoimmune diseases among individuals living with human immunodeficiency virus infection and acquired immune deficiency syndrome (HIV/AIDS) have also been studied by variety of ELISA-based analytical platforms [13]. It has been found that infected patients with HIV had higher risk of developing Sjögren syndrome, psoriasis, systemic lupus erythematosus, autoimmune haemolytic anaemia and uveitis [14]. ELISA assay has revealed that low IgG antibody responses to the pathogens may be the fundamental disorder in this kind of diseases [15]. A number of ELISA based platforms for HIV detection were marketed and are available for the end users in clinics and hospitals.

2.1.3.2 Humoral Immunity

ELISA has shown great potentials in studying the humoral response of the immune system towards different classes of infections as well. Humoral immunity response involves the substances (antibodies and other components) that exist in the body fluids [16]. Monitoring and measurement of these components are of great importance [16].

As an example, leprosy is a treatable infection that is considered to be a major issue in developing countries [17]. ELISA has been widely applied to predict the progression of this disease in infected individuals. In particular, paper-based ELISA

platforms and lateral flow test strips served the clinical practice for detection of this disease in endemic areas with limited access to the centralized laboratories [17].

ELISA has also been employed for the detection of plasmatic antibodies against antigenic peptides of human endogenous retrovirus (HERV), in line with the etiology of multiple sclerosis [18]. The careful monitoring of the immuno biomarkers associated with HERV is of great importance for analyzing the progression of the illness, especially during the interferon beta (IFNβ) therapy [18].

2.1.4 Diagnosis

In the area of diagnosis, ELISA has proven to be a capable platform applied worldwide for detecting variety of disease types in human and animals. A number of different commercial ELISA kits are available in the market for detection of HIV [19], Influenza [20], Dengue fever [21–24], Ebola [25], Chagas disease [26], Leishmaniasis [27], Lyme disease [28], West Nile virus [29], among others. Even in plants pathology, ELISA technique is attracting increasing attention. ELISA has successfully overcome the drawbacks of the previous serological analyses performed in phyto-diagnosis [30].

In this section, a brief summary on the current diagnosis applications of ELISA is provided.

2.1.4.1 Pregnancy Test

A number of different biomolecular entities including human chorionic gonadotropin (hCG), luteinizing hormone (LH), follicle stimulating hormone (FSH), estriol (E3), and thyrotrophin-stimulating hormone (TSH) [31] can be expressed due to the pregnancy. ELISA can detect some of these proteins from the maternal blood, saliva, or urine at the early stages of the pregnancy [32]. HCG is one of the common hormones that can be detected by ELISA during the first month after fertilization. Another biomolecule associated with pregnancy is estriol (E3) that can be detected with ELISA in the saliva at the 6th week of pregnancy.

Specific ELISA pregnancy tests were developed for animals as well [33]. ELISA can also be used as a reliable method for measuring congenital infections such as HIV or toxicoplasmosis during the pregnancy [34, 35].

To maximize detection sensitivity and accuracy for identifying pregnancy complications in the early stages, marker panels were developed, which are capable of monitoring/measuring multiple markers in the samples. The target biomolecules are activin A, inhibin A, progesterone, A disintegrin and metalloprotease-12 (ADAM-12), pregnancy-associated plasma protein A (PAPP-A), pregnancy specific B_1-glycoprotein (SP_1), placental-like growth factor (P-LGF), vascular endothelial growth factor (VEGF), glycodelin (Glyc), and human corionic gonadotropin (hCG), among others [36].

2.1.4.2 Cancer Detection

Highly sensitive detection of cancer provides with the early stage diagnostic, which is crucial for patient survival. Cancer biomarkers, however, are some of the most challenging biomolecular entities as target analytes. Advancements of ELISA technique has promised its application in detection of cancer biomarkers.

Zhou et al. applied a gold nanoparticle layers (GNPL) in ELISA to amplify the detection signal, which provided with a lower limit of detection (LOD). In this technique, plasma spiked with carcinoembryonic antigen (CEA) were used as the representative biomarker, proving that a straightforward and cost-effective GNPL-based sandwich ELISA holds a clinical relevance.

Vazquez-Villegas et al. integrated chemically designed poly methacrylate microspheres into the routine ELISA to detect microRNA-21 within this very convectional platform that is typically incapable of microRNA recognition. Presence of active functional groups on the surface of these spheres highly promoted analyte-surface interaction via variety of physical forces, which has subsequently resulted in the detection of microRNA-21. This exogenous miRNAs in blood serum were found to be inversely correlated to breast cancer incidence in humans [37].

Sometimes the tested specimens are hard to be obtained. Therefore, even the small sample volume is highly valuable. For instance, in the case of ovarian cancer, the glycoprotein CA125 present in the serum is the appropriate choice of biomarker for timely detection [38]. Scholler et al. developed a cost-effective ELISA-based platform for CA125 detection that requires a few microliters of serum. This microsphere integrated sandwich assay incorporates CA125 with other markers and uses the immobilized antibodies on the surface of the spheres to capture the target proteins. This platform has proven to be comparable to the commercially available detection techniques, while requiring only 15 μL of the sample [38].

2.1.4.3 Detection of the Infectious Diseases

Even to date, ELISA-based infectious serology marks one of the most reliable means for accurate diagnosis and prognosis. There is a broad range of developed and marketed state-of-the-art assays for the detection of infectious agents. ELISA has offered a high throughput detection in three classes of infectious diseases:

1. Sexually Transmitted Diseases (STDs) is a class of infectious diseases that has targeted adults in developing countries. A number of different ELISA platforms were designed and commercialized for sensitive and selective detection of STDs including HIV, hepatitis, syphilis, chlamydia.
2. Regional or endemic diseases, often referred to as tropical diseases are wide spread in tropical and subtropical regions. They might appear to be mild/symptomless with serious and chronic consequences. Dengue, chagas,

borreliosis, and yellow fever are some of the examples of this class of fatal diseases among others. While existing techniques lack timely detection of such illnesses, advances in ELISA platforms have shown great promises in offering early and effective diagnosis.

3. TORCH refers to Toxoplasma, "Other infections", Rubella, Cytomegalovirus, Herpes simplex, which is a group of viral pathogens that may result in prenatal infections. This class of infectious diseases can be a potential threat to the unborn children. Illnesses such as syphilis, hepatitis B, Epstein-Barr virus, varicella-zoster virus, HIV fall under the category of "Other infections" that might also result in serious consequences for the fetus. Commercialized ELISA platforms successfully target these infectious agents in the current clinical practice.

In Chap. 5 of this book, a thorough review on the latest advances of ELISA in the area of diagnosis will be provided.

2.1.5 Toxicology

Toxicology involves studying the adverse effects of chemical compounds on the living organisms. This area covers diagnosis and curing the effects of toxins (antigenic agents from plant or animal origins) as well as toxicants (toxic substances released into the environment). The correlation between the dosage of the toxic materials and its effects on the exposed organism, routes of the exposure, origins of the toxic substances and characteristics of the affected organs are the major concentrations in toxicology study. Few of the examples, among others, are mentioned in this section as follows:

Competitive ELISA has a long history of being applied for detection of aflatoxin B_1, one of the known toxins from rice. Developed immunoassay for aflatoxin monitoring is rapid, and straightforward, while offering desirable specificity and sensitivity [39]. Competitive assay developed for this purpose was also reported to have a considerably long shelf life (at least 12 months at room temperature) [39].

In another study, Bio-Quant direct ELISA was employed for regular screening of drugs such as amphetamine and methamphetamine in biological fluids [40]. To analyze cross-reactivity of the compounds, predetermined concentrations of common amphetamine-type substances, designer analogues, and putrefactive amines were measured. Obtained data indicated that the Bio-Quant direct ELISA technique was rapid and reliable for the presumptive screening of amphetamine and methamphetamine in forensic samples [41].

2.1.6 Drug Monitoring and Pharmaceutical Industry

ELISA techniques have also found variety of applications in screening certain classes of drugs in plasma. The conventional therapeutic drug monitoring (TDM) strategies monitor drug levels in the plasma samples [42]. TDM also provides information regarding the treatment procedure allowing physicians to examine if the medication is present in patient's body [43]. However, the conventional TDM technique is expensive and technically demanding.

As an alternative strategy, ELISA-based TDM has been introduced as a facile and cost-effective method for measuring the concentrations of the drugs in plasma samples. In particular, the aim of the study was to assess the plasma lopinavir (LPV) levels of by TDM-ELISA in youths with perinatally acquired HIV [44].

In another study, an ELISA-based platform was employed for monitoring the level of antidrug antibodies in patients receiving treatment for rheumatoid arthritis and inflammatory bowel disease [45]. This strategy shows that ELISA incorporates those features identified in the literature as important for the accurate analysis of antidrug antibodies providing a relatively simple and low-cost assay for therapeutic drug monitoring [45]. Offering a high specificity in immunoassays for therapeutic proteins is an important consideration, when such assays are used to assess the pharmacokinetics, bioequivalence and toxicokinetics studies [46, 47].

2.1.7 Transplantation

When transplantation is required, the pre-transplant cross-matching test represents one of the most important steps for a successful relocation of the organ. Complement-dependent cytotoxicity cross-match (CDC-CM) assay was developed almost four decades ago to assess the compatibility of the given organ into the body of the receptor. Selecting recipients without donor-specific antibodies is of crucial importance to increase the survival rate in the patients who are subject to the transplantation. In particular, CDC-CM plays a vital role for the recipients who undergo treatments with special drugs/therapeutic antibodies or suffer from autoimmune diseases.

CDC-CM test, however, requires lymphocytes isolation from the donors, which typically has a limited availability [48]. ELISA-based cross-matching test has demonstrated to be an adequate substitute procedure for such analysis. Schlaf et al. reported an ELISA-based cross-matching approach for identifying donor-specific anti-human leukocyte antibodies (HLA) by using deep-frozen blood or spleen detergent lysate from a deceased donor [49]. This strategy permits the cross-matching comparison to be frequently performed between the recipients' anti-HLA antibody and the donors' historically identified HLA types to monitor any incompatibility between the examined samples [49].

ELISA-LATM (One Lambda Inc.) assay is another example of the ELISA-based technology that has been tested on patients who underwent renal transplants. All patients participated in this study had their pre-transplant sera analyzed by the LATM assay prior to the actual transplantation. The clinical, biochemical, and histopathological examinations were then performed to follow-up the progress of the recipients [50]. From a total number of 164 studied patients, 149 received organs from live donors and 15 from the deceased donors. In general, 36% of the patients have experienced the organ rejection. This study shows that 100% of the patients for whom ELISA-LATM test predicted the rejection chance, in fact rejected the donor's organs, while there were a number of patients for whom ELISA-LATM fell short in predicating the chance of rejection. In an over view, however, the technique proves promising, particularly in the case of transplantation from the cadavers [50].

In the case of liver transplantation, the survival rate for ABO-incompatible (ABO-I) recipients is relatively high. It is, therefore, of a great importance to develop effective and rapid measurement of anti-A and anti-B antibodies in patients prior to receiving the organs [51]. A novel class of ELISA has been developed to monitor such antibodies in the recipients. Proposed ELISA method proved potent in measuring anti-A and anti-B antibodies at the earlier stage than the previously applied technique, agglutination. Therefore, this strategy is capable of contributing to a timely treatment of humoral rejection due to ABO-I [51].

References

1. Peng J, Meng X, Deng X, Zhu J, Kuang H, Xu C (2014) Development of a monoclonal antibody-based sandwich ELISA for the detection of ovalbumin in foods. Food Agric Immunol 25:1–8
2. Asensio L, González I, García T, Martín R (2008) Determination of food authenticity by enzyme-linked immunosorbent assay (ELISA). Food Control 19:1–8
3. Ivens KO, Baumert JL, Taylor SL (2016) Commercial milk enzyme-linked immunosorbent assay (ELISA) kit reactivities to purified milk proteins and milk-derived ingredients. J Food Sci 81:T1871–T1878
4. Pizza M, Scarlato V, Masignani V, Giuliani MM, Arico B, Comanducci M et al (2000) Identification of vaccine candidates against serogroup B meningococcus by whole-genome sequencing. Science 287:1816–1820
5. Miura K, Orcutt AC, Muratova OV, Miller LH, Saul A, Long CA (2008) Development and characterization of a standardized ELISA including a reference serum on each plate to detect antibodies induced by experimental malaria vaccines. Vaccine 26:193–200
6. Enterprise VWGot GHV (2015) HIV vaccine-induced sero-reactivity: a challenge for trial participants, researchers, and physicians. Vaccine 2015(33):1243–1249
7. Smalley C, Erasmus JH, Chesson CB, Beasley DW (2016) Status of research and development of vaccines for chikungunya. Vaccine 34:2976–2981
8. Janeway CA Jr, Travers P, Walport M, Shlomchik M (2001) Immunobiology, 5th edn. The Immune System in Health and Disease. New York: Garland Science 2001; ISBN-10: 0-8153-3642-X

9. Orsolini G, Snyder M, Crowson C, Frinack J, Kevin M (2016) THU0327 Comparison of Immunoenzymatic Assay and Crithidia Immunofluorescence Test for The Detection of anti-Double Strand DNA Antibodies in Patients with Systemic Lupus Erythematosus. BMJ Publishing Group Ltd
10. Uchida K, Nakata K, Carey B, Chalk C, Suzuki T, Sakagami T et al (2014) Standardized serum GM-CSF autoantibody testing for the routine clinical diagnosis of autoimmune pulmonary alveolar proteinosis. J Immunol Methods 402:57–70
11. Grammatikos AP, Tsokos GC (2012) Immunodeficiency and autoimmunity: lessons from systemic lupus erythematosus. Trends Mol Med 18:101–108
12. Hsu C-K, Huang H-Y, Chen W-R, Nishie W, Ujiie H, Natsuga K et al (2014) Based ELISA for the detection of autoimmune antibodies in body fluid—the case of bullous pemphigoid. Anal Chem 86:4605–4610
13. Yen Y-F, Chuang P-H, Jen I-A, Chen M, Lan Y-C, Liu Y-L et al. (2016) Incidence of autoimmune diseases in a nationwide HIV/AIDS patient cohort in Taiwan, 2000–2012. Ann Rheum Dis. annrheumdis-2016-209815
14. Yen Y-F, Lan Y-C, Huang C-T, Jen I-A, Chen M, Lee C-Y et al (2017) Human immunodeficiency virus infection increases the risk of incident autoimmune hemolytic anemia: a population-based cohort study in Taiwan. J Infect Dis 216:1000–1007
15. Terato K, Do CT, Cutler D, Waritani T, Shionoya H (2014) Preventing intense false positive and negative reactions attributed to the principle of ELISA to re-investigate antibody studies in autoimmune diseases. J Immunol Methods 407:15–25
16. Akintude ME, Heuer L, Van de Water J (2013) Immune abnormalities and autism spectrum disorders. Elsevier Inc., The Neuroscience of Autism Spectrum Disorders
17. Bobosha K, Fat EMTK, van den Eeden SJ, Bekele Y, van der Ploeg-van JJ, Claudia J et al (2014) Field-evaluation of a new lateral flow assay for detection of cellular and humoral immunity against Mycobacterium leprae. PLoS Neglected Trop Dis 8:e2845
18. Mameli G, Cossu D, Cocco E, Frau J, Marrosu MG, Niegowska M et al (2015) Epitopes of HERV-Wenv induce antigen-specific humoral immunity in multiple sclerosis patients. J Neuroimmunol 280:66–68
19. Nandi S, Maity S, Bhunia SC, Saha MK (2014) Comparative assessment of commercial ELISA kits for detection of HIV in India. BMC Res Notes 7:436
20. Tarigan S, Indriani R, Durr PA, Ignjatovic J (2015) Characterization of the M2e antibody response following highly pathogenic H5N1 avian influenza virus infection and reliability of M2e ELISA for identifying infected among vaccinated chickens. Avian Pathol 44:259–268
21. Hunsperger EA, Yoksan S, Buchy P, Nguyen VC, Sekaran SD, Enria DA et al (2014) Evaluation of commercially available diagnostic tests for the detection of dengue virus NS1 antigen and anti-dengue virus IgM antibody. PLoS Neglected Trop Dis 8:e3171
22. Welch RJ, Chang G-JJ, Litwin CM (2014) Comparison of a commercial dengue IgM capture ELISA with dengue antigen focus reduction microneutralization test and the Centers for Disease Control dengue IgM capture-ELISA. J Virol Methods 195:247–249
23. Hosseini S, Ibrahim F, Djordjevic I, Rothan HA, Yusof R, Cvd Marel et al (2014) Synthesis and characterization of methacrylic microspheres for biomolecular recognition: ultrasensitive biosensor for dengue virus detection. Eur Polym J 60:14–21
24. Hosseini S, Azari P, Farahmand E, Gan SN, Rothan HA, Yusof R et al (2015) Polymethacrylate coated electrospun PHB fibers: an exquisite outlook for fabrication of paper-based biosensors. Biosens Bioelectron 69:257–264
25. Schieffelin J, Moses LM, Shaffer J, Goba A, Grant DS (2016) Clinical validation trial of a diagnostic for Ebola Zaire antigen detection: design rationale and challenges to implementation. Clinical Trials 13:66–72
26. Aria L, Acosta ME, Guillen Y, Rojas A, Meza T, Infanzón B (2016) ELISA Chagas test IICS V. 1 evaluation for the diagnosis of Chagas disease. Memorias del Instituto de Investigaciones en Ciencias de la Salud 14:7–13

27. Lauricella MA, Maidana CG, Frias VF, Romagosa CM, Negri V, Benedetti R et al (2016) An rK28-based immunoenzymatic assay for the diagnosis of canine visceral leishmaniasis in latin America. Am J Trop Med Hyg 95:92–98
28. Hinckley AF, Connally NP, Meek JI, Johnson BJ, Kemperman MM, Feldman KA et al (2014) Lyme disease testing by large commercial laboratories in the United States. Clin Infect Dis 59:676–681
29. Prince HE, Lapé-Nixon M, Givens TS, Bradshaw T, Nowicki MJ (2017) Elimination of falsely reactive results in a commercially-available West Nile virus IgM capture enzyme-linked immunosorbent assay by heterophilic antibody blocking reagents. J Immunol Methods 444:24–28
30. Boonham N, Kreuze J, Winter S, van der Vlugt R, Bergervoet J, Tomlinson J et al (2014) Methods in virus diagnostics: from ELISA to next generation sequencing. Virus Res 186:20–31
31. Wingeier M, La Marca-Ghaemmaghami P, Zimmermann R, Ehlert U (2017) Is salivary estriol detectable in very early pregnancy? J Matern-Fetal Neonatal Med 30:228–232
32. Chard T (1992) Pregnancy tests: a review. Human Reprod 7:701–710
33. Karen A, De Sousa NM, Beckers J-F, Bajcsy ÁC, Tibold J, Mádl I et al (2015) Comparison of a commercial bovine pregnancy-associated glycoprotein ELISA test and a pregnancy-associated glycoprotein radiomimmunoassay test for early pregnancy diagnosis in dairy cattle. Anim Reprod Sci 159:31–37
34. Al-Harthi SA, El-Bali M, Zaglool DA, Khodari YA (2016) Appraisal of prenatal anti-toxoplasma gondii (IgG+ IgM)-IHA/IgM-ELISA screening in single samples via IgG avidity test. J Egypt Soc Parasitol 46:201–208
35. Makunyane L, Moodley J, Titus M (2017) HIV transmission in twin pregnancy: maternal and perinatal outcomes. South Afr J Infect Dis 32:54–56
36. Senapati S, Sammel MD, Butts SF, Takacs P, Chung K, Barnhart KT (2016) Predicting first trimester pregnancy outcome: derivation of a multiple marker test. Fertil Steril 106(1725–32):e3
37. Chin AR, Fong MY, Somlo G, Wu J, Swiderski P, Wu X et al (2016) Cross-kingdom inhibition of breast cancer growth by plant miR159. Cell Res 26:217–228
38. Scholler N, Crawford M, Sato A, Drescher CW, O'Briant KC, Kiviat N et al (2006) Bead-based ELISA for validation of ovarian cancer early detection markers. Clin Cancer Res 12:2117–2124
39. Kolosova AY, Shim W-B, Yang Z-Y, Eremin SA, Chung D-H (2006) Direct competitive ELISA based on a monoclonal antibody for detection of aflatoxin B1. Stabilization of ELISA kit components and application to grain samples. Anal Bioanal Chem 384:286–294
40. Apollonio LG, Whittall IR, Pianca DJ, Kyd JM, Maher WA (2007) Matrix effect and cross-reactivity of select amphetamine-type substances, designer analogues, and putrefactive amines using the Bio-Quant direct ELISA presumptive assays for amphetamine and methamphetamine. J Anal Toxicol 31:208–213
41. Laloup M, Tilman G, Maes V, De Boeck G, Wallemacq P, Ramaekers J et al (2005) Validation of an ELISA-based screening assay for the detection of amphetamine, MDMA and MDA in blood and oral fluid. Forensic Sci Int 153:29–37
42. Fraaij PL, Rakhmanina N, Burger DM, de Groot R (2004) Therapeutic drug monitoring in children with HIV/AIDS. Ther Drug Monit 26:122–126
43. Nso AP, Larru B, Bellón JM, Mellado MJ, Ramos JT, González MI et al (2010) Comparison of levels of antiretroviral drugs with efficacy in children with HIV infection. Indian J Pediatr 77:397–402
44. Prinapori R, Rosso R, Di Biagio A, Miletich F, Furfaro E, Taramasso L et al (2014) Pharmacokinetics of lopinavir determined with an ELISA test in youths with perinatally acquired HIV. Indian J Pediatr 81:856–860
45. Hock BD, Stamp LK, Hayman MW, Keating PE, Helms ET, Barclay ML (2016) Development of an ELISA-based competitive binding assay for the analysis of drug

concentration and antidrug antibody levels in patients receiving adalimumab or infliximab. Ther Drug Monit 38:32–41
46. Toon S (1996) The relevance of pharmacokinetics in the development of biotechnology products. Eur J Drug Metab Pharmacokinet 21:93–103
47. Bloom J, Dean RA (2003) Biomarkers in clinical drug development. CRC Press, Boca Raton, FL
48. Lee P-C, Ozawa M, Hung C-J, Lin Y-J, Chang S-S, Chou T-C (2009) Reappraisal of HLA antibody analysis and crossmatching in kidney transplantation. In Transplantation proceedings, Elsevier, pp 95–98
49. Schlaf G, Stöhr K, Rothhoff A, Altermann W (2015) ELISA-based crossmatching allowing the detection of emerging donor-specific anti-HLA antibodies through the use of Stored Donors' cell lysates. Case reports in transplantation
50. Chacko M, Mathan A, Daniel D, Basu G, Varughese S (2013) Significance of pre-transplant anti-HLA antibodies detected on an ELISA mixed antigen tray platform. Indian J Nephrol 23:351
51. Satoh A, Kawagishi N, Minegishi M, Takahashi H, Akamatsu Y, Doi H et al (2007) Development of a novel ELISA for detection of anti-A and anti-B antibodies in recipients of ABO-incompatible living donor liver grafts. Tohoku J Exp Med 211:359–367

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